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EDITED BY
HERBERT S. LANGFELD, PRINCETO ERSITY

UNIVERSITY OF OWA
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No. XV

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CHRISTIAN A. RUCK

WITH THE COÖPERATIO
LEE EDWARD TRA

SHED FOR THE AMERICAN PSYCHOLOG OCIATION BY
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HERBERT S. LANGFELD, PRINCETON UNIVERSITY

HOWARD C. WARREN, PRINCETON UNIVERSITY (*Review*)
S. W. FERNBERGER, UNIVERSITY OF PENNSYLVANIA (*J. Exper. Psychol.*)
W. S. HUNTER, CLARK UNIVERSITY (*Index*)
E. S. ROBINSON, YALE UNIVERSITY (*Bulletin*)

UNIVERSITY OF IOWA STUDIES IN PSYCHOLOGY

No. XV

EDITED BY
CHRISTIAN A. RUCKMICK
WITH THE COÖPERATION OF
LEE EDWARD TRAVIS

PUBLISHED FOR THE AMERICAN PSYCHOLOGICAL ASSOCIATION BY
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PREFACE

In addition to the published experimental studies in the fields of the psychology of music, speech, and emotion there have recently accumulated a number of thoroughgoing investigations in clinical psychology under the guidance of Dr. Lee Edward Travis, Director of the Psychological Clinic. While many similar studies made by Dr. Travis's students have appeared in technical, physiological, and neurological journals, we thought it advisable to issue a clinical number of the Iowa Studies in Psychology so that many psychologists who read this Monograph Series would become more intimately acquainted with them.

With two exceptions, the manuscripts printed in this number were prepared and revised first of all by Dr. Travis and his students, and the editor made only minor changes in order to bring the material into conformity with our usual standards in the Series. The editor wishes to acknowledge the fine spirit of coöperation on the part of Dr. Travis which helped considerably to make this Volume possible. It illustrates in general the attitude which obtains between different departments and colleges at the University of Iowa.

Two studies, completed under the direction of Dr. F. B. Knight, have been added to this volume because they treat of still other phases of clinical psychology. Dr. McClure presents some results obtained by means of testing techniques revealing the unevenly developed capacities of the feebleminded and Dr. Herbert D. Williams discusses the underlying causes of social maladjustment among delinquent children.

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INTRODUCTION

Since 1927 there have been published by the writer and his students over a score of studies from the psychological laboratories in the Psychopathic Hospital at the University of Iowa. Because they have been basically neurophysiological in scope and interest the majority of them have appeared in the various medical rather than in the various psychological journals. Inasmuch as an ever quickening and mutually helpful appreciation is binding together the two sister interests, psychology and neurophysiology, contributions in one field are coming more and more to be welcomed by workers in the other field. Because of this it seems appropriate to publish the following clinical and neurophysiological studies in this psychological periodical.

All but two of the investigations are outgrowths of previous work from this laboratory and continue the systematic research program inaugurated for the purpose of gaining a better insight into both organic and functional neuromuscular derangements. Stutterers, lispers, aphasics, and psychiatric and neurologic cases have been scouted. Various approaches, including the phonophotographic, the eye photographic, the biochemical (pH determinations), the action-current and the chronaxie, have been utilized.

In the present volume all studies but three in one way or another deal with the problem of stuttering. These studies of stuttering are presented in an order indicative of the way the larger research program has been envisaged. Our attention is directed first to symptomatology. Dr. Bryngelson's study is a further analysis and elucidation of the variegated vocal manifestations of stutterers during stuttering. He adopted the phonophotographic method, which has been constantly improved in this laboratory until it now incorporates the use of high quality broadcasting equipment and an oscillograph of excellent frequency characteristics.

The studies of Doctors Murray, Kelly, and Jasper inquired into the fundamental nature of stuttering and involved an analysis of factors which differentiate stutterers from normal speakers in other than their speech acts. For these studies standardized test material, derived from education and psychology, as well as specifically developed laboratory techniques were used. In evaluating the silent reading characteristics and abilities of stutterers Dr. Murray compared and correlated the results obtained from standardized reading tests and breathing and eye movements. Dr. Kelly used standardized reading tests, recordings of breathing, and specially devised laboratory techniques to discover some possible common factors in reading and speech disability cases. Dr. Jasper critically evaluated some formerly used speech clinic tests, developed some new and significant ones, and applied the now well known chronaxie methods to an understanding of stuttering.

Dr. Fagan's first paper presents a carefully controlled study of a certain kind of management of stuttering. His second report concerns an interesting case of stutter-writing. Dr. Dysinger's research consisted of an extension of the action current technique to an interpretation of neurological conditions underlying neurologic and psychiatric disturbances.

The writer wishes to express formally his appreciation of the serious purpose of those of his students whose contributions make up the present volume. The necessarily close associations in the laboratory led to pleasant comradeships which constitute no small part of the director's joy in assuming responsibility for their research projects. The writer desires to record here his thanks to the editor of the Iowa Studies, Professor Ruckmick, for his kind and expert help in the preparation of the manuscripts for publication.

LEE EDWARD TRAVIS

CONTENTS

A PHOTOPHONOGRAPHIC ANALYSIS OF THE VOCAL DISTURBANCES IN STUTTERING

by

BRYNG BRYNGELSON

I. Introduction. It is usually conceded that the manifestations of stuttering offer certain clues in regard to the nature of the disturbance. It is also generally conceded that many symptoms of stuttering are not detectable by direct observation. Therefore a study in which refined methods are used to detect and record more subtle evidences of disturbances in the functioning of the speech mechanism during stuttering might be valuable.

The present study was undertaken to detect and record some of the more subtle evidences of disturbances in the functioning of the speech mechanism during stuttering. Our knowledge of the symptoms of stuttering is limited undoubtedly because of a lack of techniques for disclosing all that may be occurring in the organism during any given period. Various biochemical, neurophysiological, and psychological changes which occur during stuttering are undoubtedly pathognomonic and consequently would be of great value if we were able to detect them. To a partial realization of the achievement of this goal we have brought a refined method. It is capable of demonstrating many relatively obscure but certainly significant neuromuscular dysintegrations obtaining during stuttering.

Previous studies further suggest the value of a phonophotographic analysis of the stutterer's voice and speech. Such have concerned themselves largely with pitch changes in, and duration of, tones in various types of both normal and abnormal speech. The studies of *Scripture, Simon, Gray, Travis, Root,* and *Miles* are of particular significance for the present report. They will be evaluated later in connection with the presentation and discussion of our findings.

II. Apparatus and procedure. The apparatus employed in this study is the same as that used by *Travis* and *Dorsey* (12). It consisted of a Jenkins and Adair condenser microphone with one additional stage of high quality amplification, a Westinghouse oscillograph and a General Radio Type 377 low frequency oscillator.

The condenser microphone was of the same type as those used in the large broadcasting stations and in motion picture recording. It possesses a stretched duralumin diaphragm placed 0.001 in. from a properly designed and insulated backplate. A potential of 180 v. was impressed across these two plates (diaphragm and backplate) so that when the voice waves struck the diaphragm causing it to vary in accordance with their pressure variations, the electrical charge on the plates varied. Since the charging current flowed through a very high resistance the variations in the electrical charge caused voltage drops across the resistance which were impressed across the grid and filament of the vacuum tube. The voltage drops were a replica of the voice waves. A single stage amplifier using a UX-112-A vacuum tube was an integral part of the microphone. In order to avoid long leads it was housed in the microphone case. The voltage output-frequency curve for this complete unit is flat between 100 and 5000 ~ per sec.

In order to obtain sufficient energy to actuate the oscillograph element it was necessary to add to the microphone an additional stage of amplification (Fig. 1). It consisted of a high quality 200 ohm line-to-tube input transformer, a gain control potentiometer, and a UX-112-A vacuum tube which worked into a tube-to-2 ohm impedance output transformer. The latter transformer was used to match the impedance of the oscillograph element to that of the tube to insure fidelity of reproduction and maximal power output. The condenser microphone and the additional stage of amplification were operated from batteries.

A standard oscillograph element with a natural period of 3500 complete ~ per sec. was used for recording the voice waves. In our optical system it had a deflection of 1 in. per 100 milliamperes of current. It was approximately critically damped. The fre-

quency deflection curve for the additional stage of amplification and this standard oscillograph element is practically flat between 100 and 3500 complete ~ per second, being down 3 db at 90 ~ and 5.5 db at 6000 ~. Thus the over-all (the condenser microphone, the one additional stage of amplification, and the standard oscillograph element) frequency-deflection values were practically equal between these two frequency limits.

The oscillator activating a super-sensitive oscillograph element of a sensitivity of 4.5 in. deflection per 100 milliamperes fur-

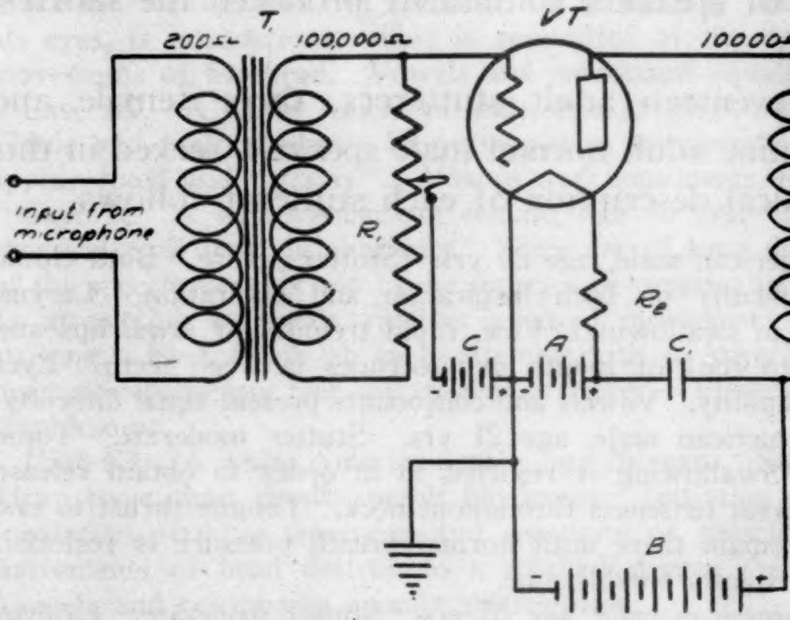

FIG. 1. A wiring diagram of the additional stage of amplification for the condenser microphone. T_1=line-to-tube transformer, T_2=tube-to-2 ohm transformer, R_1=200,000 ohm amplitude control potentiometer, R_2=4 ohm fixed resistance, C=4½ vt. "C" battery, C_1=2 mfd by-pass condenser, A=6 vt. battery, B=90 vt. battery, VT=UX-112-A vacuum tube, O. E.=oscillograph element.

nished time values of .001 sec. These fine time units made it possible and practical to read wave lengths in terms of .0005 sec. without interpolation. All photographing was done on Eastman 32 mm. motion picture film.

For the main portion of the study the subject's voice and speech were photographed in easy, unemotional, conversational situations. In only two instances was it necessary consciously to embarrass the stutterer in order to elicit stuttering. Before the microphone he discussed current topics of the day, recited

verses, asked and answered questions, or entered into the conversation of the group. Recording was continued until an adequate sampling of his vocal difficulties was obtained.

For another portion of this study the stutterer was asked to change if possible his real stuttering movements to voluntarily produced, simulatory stuttering movements. Recording was continued throughout such an entire period which is designated as an attempt to change an involuntary spasm to a voluntary spasm. Both the stutterer and the normal speaker also imitated to the best of their ability the vocal disturbances of stuttering. Finally, both types of speakers voluntarily produced the shortest tone possible.

III. Subjects. Seventeen adult stutterers, three female and fourteen male, and nine adult normal male speakers served in this study. A brief clinical description of each stutterer follows.

Case I. A white American male, age 20 yrs. Stutter severe. Both clonic and tonic spasms. Difficulty on both inspiration and expiration. Larynx moves up and down as in swallowing. Fine, rapid tremors of jaws, lips and ears. Tongue cleaves to roof of mouth or protrudes between teeth. Eyes blink with remarkable rapidity. Vowels and consonants present equal difficulty.

Case II. A white American male, age 21 yrs. Stutter moderate. Tonic spasms on expiration. Swallowing is resorted to in order to obtain release from a speech block. Great tenseness throughout neck. Tongue thrust to one side of oral cavity to remain there until normal breath pressure is restored. Consonants and vowels equally troublesome.

Case III. A white American male, age 23 yrs. Stutter moderate. Evident spasms in laryngeal mechanism. Tremors of lips and eye-lids. Tongue placed forward in a fashion suggestive of thus attempting to force lips apart. Both clonic and tonic spasms in speech musculature. Vowels and consonants equally affected.

Case IV. A white American male, age 19 yrs. Stutter severe. Clonic spasms in articulatory and laryngeal mechanism in connection largely with vowels. Associative movements of eyes.

Case V. A white American male, age 24 yrs. Stutter severe. Entire speech mechanism extremely tense in attempts at speech. Often tries speaking on empty lungs with accompanying associative movements consisting of bending body forward at waist. Tonic spasms result in a jerking of head to one side simulating an attempt to "snap" the spasm. Tongue cleaves to roof of mouth. All spasms accompanied by escape of air or voice. Sound often repeated until desired one can be uttered. Frequently an entire word repeated over and over again. Under a clonic spasm-spell speech is often cluttered and inaccurate—a lateral *s* sound may appear. Vowels and consonants equally troublesome.

Case VI. A white American male, age 19 yrs. Stutter slight. Clonic spasms resulting in repetition of syllable most marked. An occasional clonic spasm appears at beginning of words. No detected associative movements. Vowels and consonants give equal difficulty.

Case VII. A white American male, age 20 yrs. Stutter severe. Both tonic and clonic spasms evident; apparently largely localized in breathing and articulatory musculature. Accompanying facial grimaces consisting of clonic spasmodic movements of jaw in sinistrad direction. Fine rapid tremors of lips which are protruded as in sucking. Eyes present staring, blank, lifeless expression. Associative movements of arms and legs more marked on left side. Vowels and consonants equally troublesome.

Case VIII. A white American male, age 25 yrs. Stutter severe. Both tonic and clonic spasms in entire speech musculature. General dysintegration of lip, laryngeal, and breathing movements. A striking "catch" in the outgoing breath stream with accompanying sharp jerking-back of head. Upon release of a tonic spasm there is a lingering tonicity expressed in the "pressing out" of the tones. In the severest blocks eyes are tightly closed. At other times evident blinking of eyes. At still other times the observer is unable to shake the feeling that this stutterer, on account of the dazed, lifeless look in his eyes, is unconscious. This is remindful of the death faint. Associative movements of forehead. Vowels and consonants equally troublesome.

Case IX. A white American male, age 22 yrs. Stutter moderately severe. Clonic and tonic spasms. Few associative movements. In tonic blocks eyes appear fixed and "glassy". Vowels and consonants equally troublesome.

Case X. A white American female, age 30 yrs. Stutter severe. Spasms practically all tonic in character. They are of long duration and occur in all of the speech muscles and in the muscles of practically all other parts of body. In attempting to speak, random athetoid movements of arms and head are striking. Eyes blank at each attempt with a lowering aside movement of head. Scarcely any free speech ever produced. Vowels and consonants equally troublesome.

Case XI. A white American male, age 20 years. Stutter moderately severe. More tonic than clonic speech blockages. Initiation of spasms preceded by inhalation, striking tenseness, and spasticity of muscles of neck. Associative movements of head destroy to a marked degree the rhythm of expression. Vowels and consonants equally troublesome.

Case XII. A Jewish female, age 20 yrs. Stutter severe. Severe tonic spasms in entire speech musculature. Lips move in all directions. Breath comes in short pants. Patient obliged to swallow before speaking normally again. After release of spasms there is a noticeable gasping of air. Associative blinking of eyes and rapid movements of lips and cheeks. Patient reports that she is a "nervous wreck" following a speech blockage. Equal difficulty with vowels and consonants.

Case XIII. A white American male, age 24 yrs. Stutter moderately severe. In anticipation of difficulty he has developed a tic-like reaction of jerking-up his entire body. During a block eyebrows rise, eyes blink, nostrils distend, and jaw quivers. Vowels are invariably repeated. They are more troublesome than consonants.

Case XIV. A white American male, age 23 yrs. Stutter severe. Tonic blocks most evident in articulatory and laryngeal musculatures. There are spasmodic contractions of eyelids and nostrils. Fine tremors of lips. As a block is released all sounds uttered explosively. When confronted with a speech spasm head is turned aside. At onset of a spasm lips and tongue appear to clamp tight. They present tremors which persist until the release of the spasm. Stuttering more pronounced on consonants.

Case XV. A white American male, age 25 yrs. Stutter moderately severe,

largely of the clonic type. Tonic spasms occur occasionally. They are focalized largely in mouth and throat. In stuttering a spasmodic "screwing up" of face is evident. Fine, rapid tremors appear in lips and eye-lids. At the height of a speech block, head is jerked violently backwards. Vowels slightly more troublesome than consonants.

Case XVI. A white American male, age 25 yrs. Stutter severe. Spasms focalized primarily in mouth and breathing apparatus. They appear most frequently toward the end of an expiration. Tongue appears to cleave tightly to roof of mouth. During a speech block eyes closed. Consonants more troublesome than vowels.

Case XVII. A white American female, age 36 yrs. Stutter moderately severe. Both clonic and tonic spasms, most apparent in articulatory musculature. Associated movements in blinking of eyes and quivering of lips. Associated emotional reactions of flushing and watering of eyes. Stutter equals a "sputter". When lips approximate in a spasm the sounds appear as "sputters". Consonants and vowels equally troublesome.

IV. Data and discussion.

(a) Pathologic Variations in the Form, Extent, and Length of Consecutive Waves

Scripture (8, 9) in 1921 reported that for normal subjects the voice waves are of approximately equal length. If changes are present they are relatively gradual and smooth. *Travis* (13) in 1927 in studying the voice and speech in casual unemotional propositional speech found that for normal speakers there are pitch variations of an aperiodic type. Neither the vibrato (periodic fluctuations in pitch of a rate of from 4 to 8 fluctuations per sec.) nor tonal fixation was found. Neither marked variations in the length nor the form of consecutive waves were detected. *Gray* (4) in 1926 in a study largely of speech which was thought expressive of "moods" (soothing, loneliness, doubt, pleading, desolation, awe, reverence, and horror) reported several types of pitch fluctuations. There were in the main the vibrato, the "drift", occurring only in inflections, the "missing cog" (one or more internal pulsations missing), and the isolated type (one big variation standing alone as a circumflex, an inverted circumflex, a double circumflex, or a double inverted circumflex). It is to be noted that in all of these variations several voice waves were involved. The changes took place through a series (in some instances a relatively short, in others a relatively long, series) of waves. *Root* (7) in 1928 in a study of both ordinary communi-

cative and emotional and dramatic speech found pitch fluctuations of both the periodic and aperiodic type in the former kind of speech production. They varied in total pitch range from one-

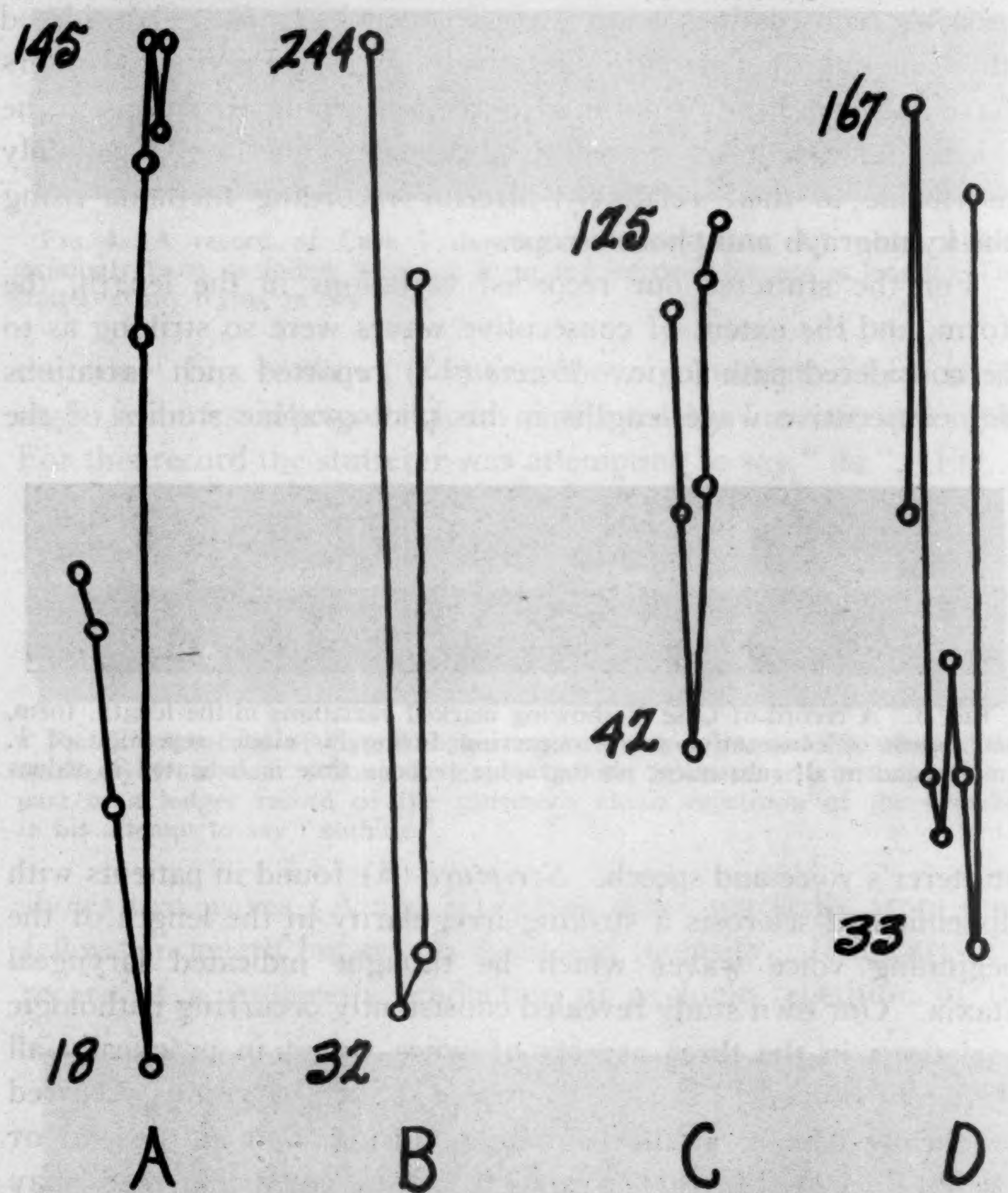

FIG. 2. Marked variations in the length of consecutive waves. Each circle indicates one wave; each vertical square represents a semitone; each horizontal square represents a time value of 0.05 sec., and the numbers represent pitch in terms of ~. A=beginning of a tone, B=middle of a tone, C=end of a tone, and D=vocalization on inhalation.

fourth of a semitone to three tones, with a mode of one or two semitones.

From these studies it appears that wave to wave fluctuations

are characteristic of normal speech. However, from a study of *Root's* graphs which present the largest of such changes, we were unable to detect a difference greater than seven semitones between possibly consecutive voice wave-frequencies. *Root* considered this amount of fluctuation relatively great. Previous workers have had very little or nothing to say concerning variations in the form and extent of consecutive waves. This fact is possibly ascribable to their relatively inferior recording methods using the kymograph and phonelescope.

For the stutterer our recorded variations in the length, the form, and the extent of consecutive waves were so striking as to be considered pathologic. *Travis* (13) reported such variations for consecutive wave lengths in his photographic studies of the

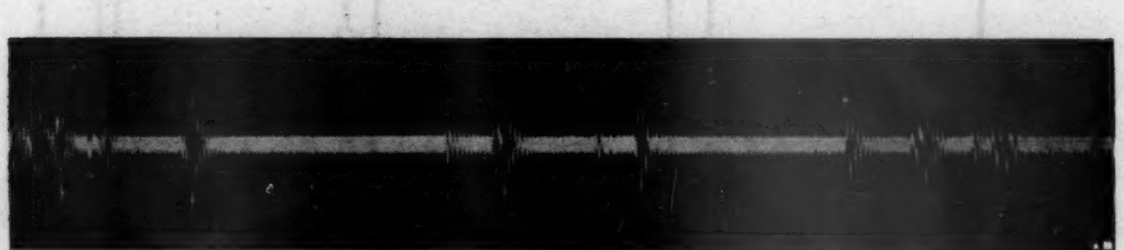

FIG. 3. A record of Case V showing marked variations in the length, form, and extent of consecutive waves occurring during his clonic repetition of *k*. In this and in all subsequent photographic records time is indicated in values of σ.

stutterer's voice and speech. *Scripture* (8) found in patients with disseminated sclerosis a striking irregularity in the length of the beginning voice waves which he thought indicated laryngeal ataxia. Our own study revealed consistently occurring pathologic variations in the three aspects of voice waves in practically all stutterers studied (15 of the 17 cases). Such variations occurred practically equally at the beginning, during, and at the end of tones (Fig. 2). In these graphs it will be noted that there may be a difference of as much as 33 semitones between consecutive wave-frequencies, a difference slightly over five times the greatest of such difference reported by *Root* for normal speakers. Fig. 3 presents a record of extreme variations in the length, form, and extent of consecutive voice waves occurring during case V's attempt to say "question". His actual production consisted of clonic repetitions of the sound *k*. When consecutive waves varied

markedly in one aspect (length, or form, or intensity) they were apt to do so in the other aspects. However, this was not always

FIG. 4. A record of Case I showing a wave (above A) which differs strikingly from its fellow waves in form and intensity but not in length. The stutterer was trying to say "do".

the case. Fig. 4 shows a wave (above A) which differs strikingly from its fellows in form and intensity but not in length. For this record the stutterer was attempting to say "do". Fig. 5

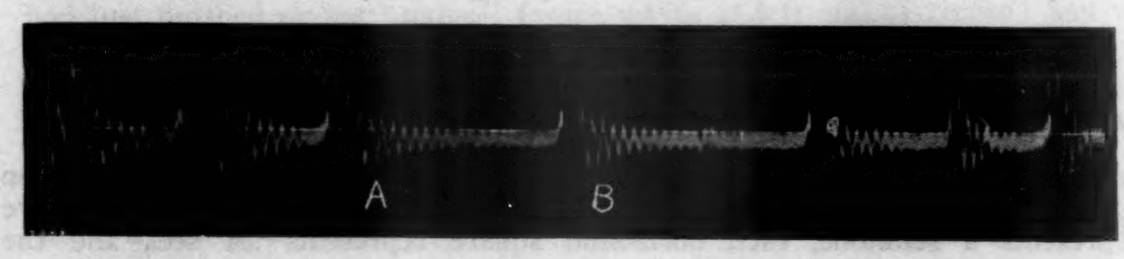

FIG. 5. A record of Case IV showing two waves (A and B) which differ markedly from their fellows in length but not in form and intensity. It is part of a longer record of the stutterer's clonic repetition of the sound ɔ in his attempt to say "nothing".

shows two waves (A and B) which differ markedly from their fellows in length but not in form and intensity. It is part of a record of a stutterer's production of a clonic repetition of the

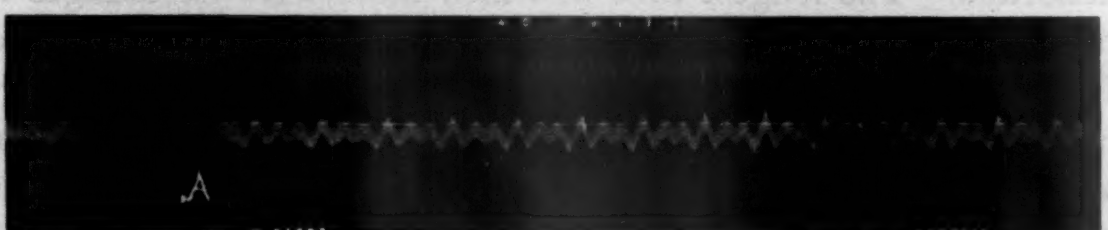

FIG. 6. A record of Case I showing a wave (A) which differs greatly from its fellows in form but not in intensity or length. The stutterer was experiencing difficulty in saying "name".

sound ɔ in his attempting to say "nothing". Fig. 6 shows a wave (above A) which differs greatly from its fellows in form but not in intensity or length. The stutterer was experiencing

difficulty in saying " name ". His photographed production was the sound *n*.

(b) Extreme Tonal Rigidity

Simon (10) found that pitch variations were characteristic not only of vocal tones but of instrumental tones. The presence of consecutive waves of exactly the same length was reported as an exception rather than as a rule. In some of the longest tones encountered in the present study in 7 of 17 cases (Fig. 7) there were found to be as many as 143 consecutive waves that did not vary one from the other so much as .0005 of a sec. in duration. In this connection it is pertinent to recall that a wave can be read in units of .0005 sec. without the need of interpolation. In Fig. 7 the speaker, a stutterer, was attempting to say his last name which

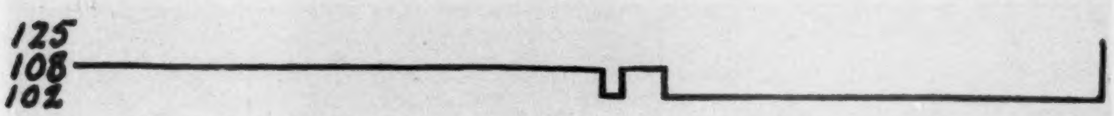

Fig. 7. Marked rigidity and prolongation of a tone in Case I's production of *b* in his attempt to say a word beginning with *b*. Each vertical square represents a semitone, each horizontal square represents .01 sec., and the numbers give pitch in ~. The tone lasted 3.6 secs.

began with *b*. His attempt resulted in the production of a single sustained tone which lasted approximately 3.5 sec. In such instances not only is the exceptional duration of the tones pathologic but the extreme degree of tonal rigidity which implies a correspondingly high degree of muscular fixation is likewise abnormal. The longest time in which there were no changes in pitch reported by *Root* (7) for his normal speakers was .01 sec. In speech there is not only no need for the absolutely constant holding of any given pitch for a considerable length of time but also no likelihood that the speaker would be able to do this. In many of the tones recorded in the present study the stutterer's voice waves were as constant in frequency as were the oscillator cycles. *Travis* (13) has reported tonal rigidity of a similarly striking order in the stutterer's tones. *Scripture* (9) found that although the epileptic's voice may show the pitch to rise and fall, it does not present the small pitch fluctuations found in all normal voices.

(c) Isolated Voice Waves

These appeared in a variety of forms in 15 stutterers. One of the most striking varieties may be termed a highly damped, transient series of oscillations (Fig. 8). For this record the stutterer had just finished saying " name " (voice waves at left end of record) and was attempting on inhalation to say the word " is ". It is to be noted that the particular series illustrated fol-

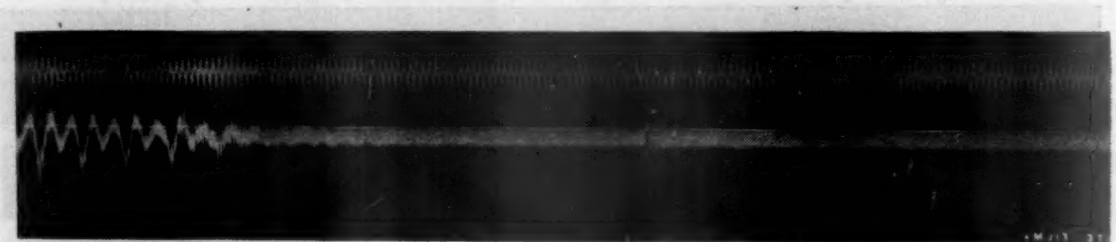

FIG. 8. A record of Case I showing a highly damped wave. The stutterer had just finished saying " name " (voice waves at left end of record) and was attempting on inhalation to say the word " is ".

lowed a tone by .066 sec. and lasts for .005 sec. Only a few oscillations took place and these at a rapid reduction in amplitude, each after the other. There were no detectable changes in the rate of the high frequency oscillations in a series 2000 per sec. In oscillatory circuits of radio engineering such a series is the

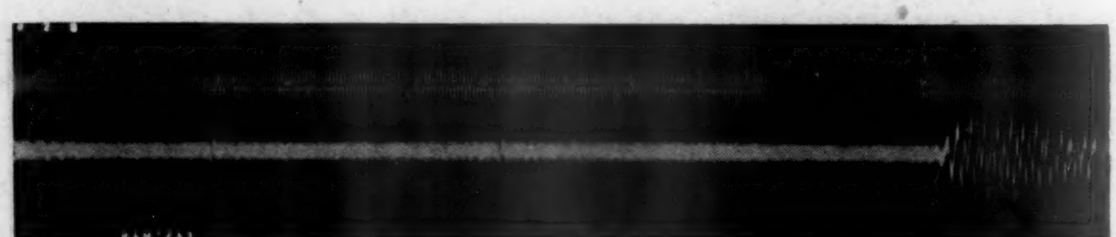

FIG. 9. A record of Case IX showing two isolated waves before a tone. The stutterer's difficulty consisted of a break between the first and second syllables in the word " library ".

result of a high resistance in the circuit. In the vocal mechanism such a series certainly indicates that a high resistance is offered to the vibrating mass. The exact nature and source of this resistance remain unknown. It must be assumed, however, that the damping constant of the resistance is very high because the acoustic spectrum of the series would undoubtedly show that the successive oscillations of the same frequency present extremely rapid decreases in their amplitudes.

Another variety of isolated waves appears to consist essentially of a single oscillation of extremely short duration (.002 sec.). In Fig. 9 two such waves or oscillations appear; one .078 sec. and the other .117 sec. before a tone. The stutterer's difficulty consisted of a break between the first and second syllables in the word "library". A careful examination of this record will reveal that the two oscillations under consideration appeared in a

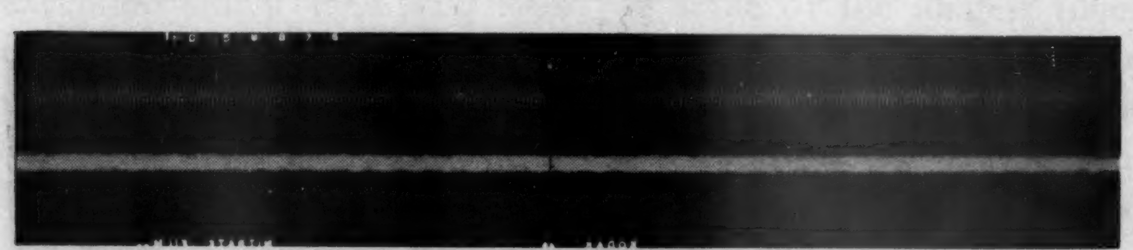

FIG. 10. A record of Case VI showing a wave consisting of an extremely abrupt change (increase) in the amplitude of the high frequency, low amplitude oscillations. The stutterer was presenting an inhalatory spasm in an attempt to begin a sentence.

relatively long series of high frequency low amplitude oscillations (2000 per sec.) which continued to the beginning of the voice waves proper. The two oscillations may be thought of as extremely sudden and brief changes in the amplitude of the high frequency low amplitude oscillations. A modification of this

FIG. 11. A record of Case X showing two "vibration couplets". The stutterer was having difficulty between clonic repetitions of the word "not".

second variety of isolated waves consisted of an extremely abrupt change (increase) in the amplitude of the high frequency, low amplitude oscillations to present a series of two larger oscillations appearing at the same rate as their smaller fellow oscillations (Fig. 10). At the time this record was obtained the stutterer was presenting an inhalatory spasm in an attempt to begin a sentence.

A third variety of isolated waves is presented in Fig. 11 which

is a record of a stutterer's clinically undetermined difficulty between a clonic repetition of the word " not ". *Travis* (13) in reporting this same phenomenon has called it a vibration couplet. In the particular record shown in Fig. 11 there are two such vibration couplets, each consisting of two complete cycles. As was noted by *Travis* we have encountered them mainly before tones. More frequently than not the couplets appear aperiodically and at varying intervals of time before a tone. They last approximately .007 sec. making the cycles within the couplet appear at a rate of approximately 300 per sec.

A fourth variety of isolated waves is seen in Fig. 12. It really amounts to two very complex waves (A) lasting .006 sec. Such

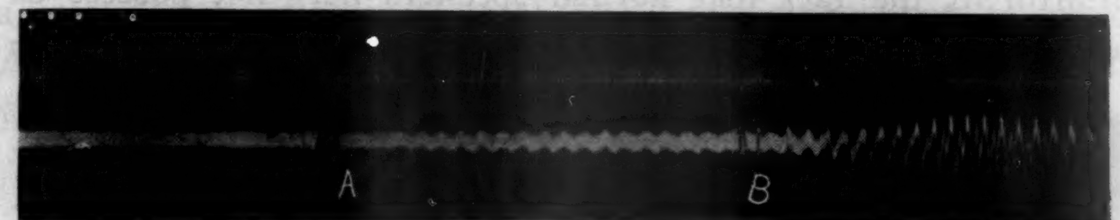

FIG. 12. A record of Case X showing one variety of isolated waves. The stutterer was presenting clonic spasms which resulted in repetitions of *k*.

waves are more frequently seen just before a tone. They are usually not only of much greater complexity but also of much larger amplitude than the waves in the other varieties we have been discussing. In this particular record the stutterer was experiencing clonic spasms which resulted in repetitions of the sound *k*. Before each characteristic vocalization the two isolated waves appeared. It may be noted that vocal disturbances were indicated by the waves marked B. Further it may be noted that between A and B there appeared sine waves of low intensity quite unlike voice waves. There is no reason to suppose, however, that they were not of vocal origin.

A fifth variety of isolated waves is presented in Fig. 13. It is significant that this record was obtained during a phase of the stutterer's difficulty presented in Fig. 11. Clinically the two stuttering periods recorded were identical. In Fig. 13 there are two series of exceedingly high frequency oscillations each series being initiated by waves of much larger excursion than their

successors. Each group made up of the oscillations of greatest amplitude lasted approximately .005 sec. while each complete series lasted approximately .015 sec. Generally such isolated groups appeared before tones.

Because in records of normal voices including those reported by other workers as well as those obtained in the present study we have never encountered such extremely brief activity as was implied in these isolated waves, we had a number of trained speakers produce the shortest tone possible. In no case were we able to obtain a tone of less than 12 voice waves. This number of waves should be considered in comparison to the single isolated waves appearing in practically all of our stutterers' records. Mindful of the fact that normal speakers may not possess as facile a mechanism for producing short tones as does the stut-

FIG. 13. A record of Case X showing another variety of isolated waves during the same speech spasm as mentioned in FIG. 11.

terer, we had all of our stutterers voluntarily make the shortest possible tone. They were not superior to our normal speakers in this respect. In view of these facts we may assume that the single isolated waves appearing during stuttering were truly characteristic of the abnormality and sharply differentiated it from normal tone production.

The various theories of vowel production did not help us very much in understanding the physiological basis of these isolated waves. In no sense could they be thought of as vowels which were characterized by continuous wave trains formed in the larynx and passing through opened passages. They were more understandable in terms of unvoiced stop consonants which were characterized by short groups of waves formed mostly by the mouth and released suddenly by opening the lips. In our records, however, we did not have even short groups of waves but single waves.

(d) Abnormal Attacks of Tones in Stuttering

Stevens and *Miles* (11) in studying the first vocal vibrations in the attack in singing found that the vocal cords do not attain full vibratory amplitude or rate immediately. The full amplitude and rate is reached in from 3 to 10 ~. The amount of breath available for tone production seemed to produce no great changes in the attack results. *Scripture* (8) reported that in advanced disseminated sclerosis the patient gasped at the start of a phrase. *Travis* (13) has noted waves of a bizarre form and of marked variations in length and intensity in the stutterer's attack in speaking.

In the present study all stutterers have been found to present a great variety of unusual vocal attacks in their attempts to speak. A very common variety is represented in Fig. 14. The stutterer was attempting to say the word " swallow ". The tone was intro-

FIG. 14. A record of Case XVI showing a series of highly damped waves differing greatly in length and intensity in another variety of abnormal tonal attacks. The stutterer was attempting to say " swallow ".

duced by a series of highly damped waves differing greatly in length and intensity. The oscillations in each highly damped series were of higher frequency than the partials of the voice waves proper. The fourth series differed greatly from its three predecessors in form while the first series differed materially from its successors in length and intensity. These highly damped waves were preceded in the record by a relatively long series of high frequency oscillations indicative of hissing. It is indeed remarkable and we believe pathological for the speech mechanism to change from producing hissing to producing highly damped waves within the short interval of time of .034 sec. The oscillations in hissing are of much higher frequency than are those in the damped waves. A slight modification of the type of disturbance in the attack of a tone as presented in Fig. 14 is pictured in

Fig. 15. The oscillations in each highly damped series of waves were of much higher frequency (2000 per sec.) than the comparable oscillations in Fig. 14. Otherwise the general patterning of the two records is similar. For this record (Fig. 15) the stutterer was having difficulty in saying " will ".

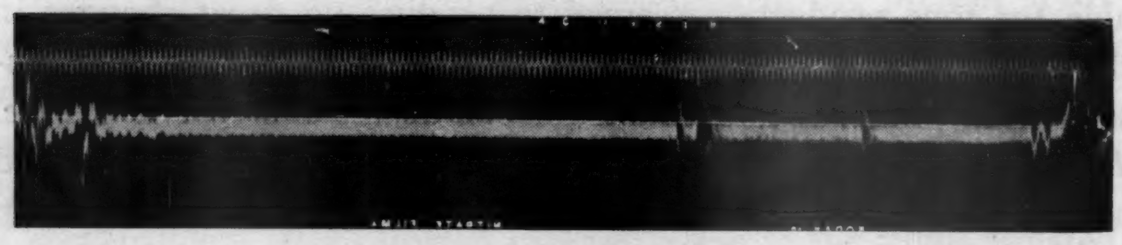

FIG. 15. A record of Case IV showing in a third variety of abnormal tonal attacks a series of highly damped waves with relatively high frequency oscillations (2000 per sec.). The stutterer was having difficulty in saying " will ".

A second common variety of unusual attack in the stutterer's tones consisted of high frequency oscillations (2000 per sec.) whose amplitudes were aperiodically varied (Fig. 16). Such high frequency oscillations usually continued to the beginning of the voice waves proper. In some records, however, there was an

FIG. 16. A record of Case III showing in a fourth variety of unusual tonal attack high frequency oscillations (2000 per sec.) whose amplitudes are aperiodically varied. The stutterer furnished an escape of breath between " how " and " ever " in an attempt to say " however ".

unusually short interval of time (.030 sec.) between the end of these oscillations and the beginning of the tone. From a clinical analysis of the stutterer's difficulties and from a photographic study of the normal speaker's attempts to reproduce the stutterer's symptoms, such high frequency oscillations as we were studying in this figure, and as were presented in Fig. 14, appeared to have been the result of a type of voiceless plosive such as *t* (Fig. 17). In Fig. 16 the stutterer was attempting to say " however ". The high frequency oscillations represented an escape of breath between " how " and " ever " the latter part of

the former word having been represented by the voice waves at the extreme left end of the film and the beginning of the latter word by those at the extreme right end of the film. The involuntary escape of breath is seen to be in a certain sense interposed between the two words but directly continuous with " ever ".

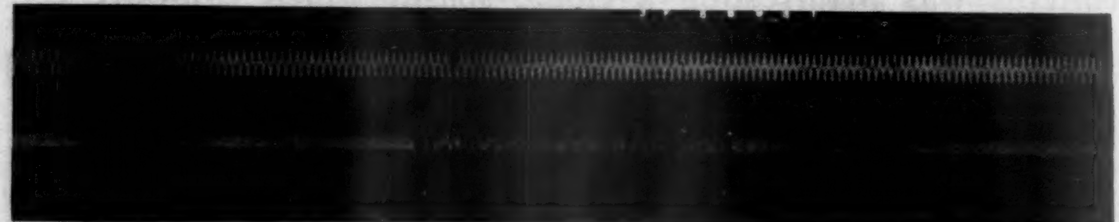

Fig. 17. A record of a normal speaker's production of a voiceless plosive *t*.

A third variety of abnormal attack of tones in stuttering is presented in Fig. 18 which is a record of a stutterer's attempt to say " Lawrence ". His actual production was a clonic repetition of *a*. The four small oscillations at the left end of the film indicated a low-pitched (67 ~) soft tone which was relatively suddenly changed with the fifth wave. This latter wave was rela-

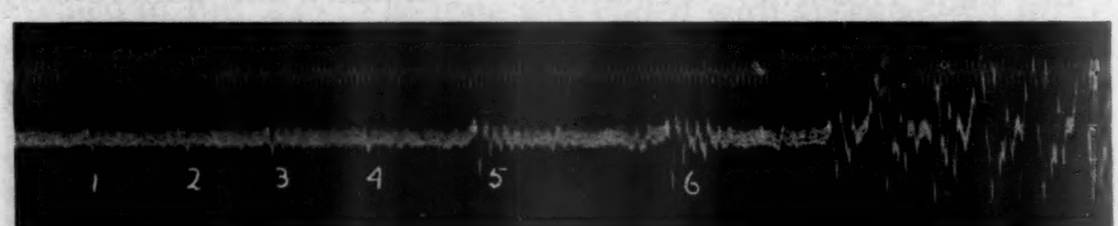

Fig. 18. A record of Case IV showing a fifth variety of abnormal attack of a tone. The stutterer was presenting a clonic repetition of *ah*.

tively large and complex. It was followed within .032 sec. by a still larger wave which in turn was followed within .027 sec. by the voice waves proper. The latter waves occurred at a rate of approximately 110 per sec. It is noteworthy that this same stutterer during the identical clonic spasm which furnished the record for Fig. 18 produced the variety of exceptional attack of a tone presented in Fig. 19. Clinically the two phases of the clonic spasm were identical. Photographically they were strikingly different. In Fig. 19 the attack consisted of waves of relatively small amplitude joined by means of a wave (A) markedly different in form from any of its fellows to the voice waves

proper. These latter were exceptionally large, implying the vocal mechanism's release from the inhibiting force manifested in the smaller waves earlier in the tone.

A fourth common abnormality of attack of tones is seen in Fig. 20. In the record of which this figure forms a part, the stutterer was manifesting a clonic spasm which clinically con-

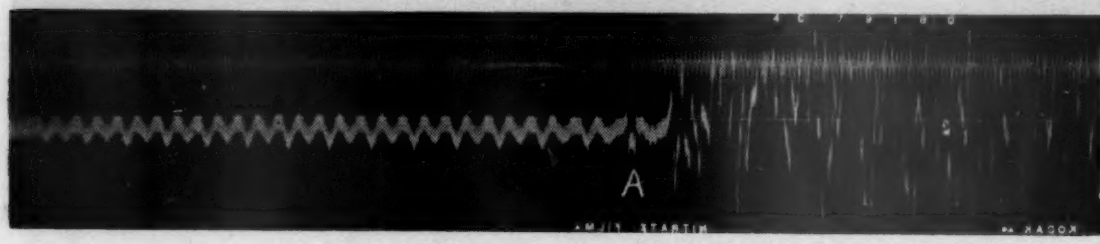

FIG. 19. A record of Case IV during the same difficulty mentioned in FIG. 18. The striking difference between the records is to be noted.

sisted of spasmodic repetition of ɔ as in " all ". Before each ɔ sound she inspired sharply to produce the breathy, extremely suddenly initiated tone seen in Fig. 20. Photographically the unusual feature of the record was the abruptness of appearance of the high frequency oscillations. Clinically the abnormality

FIG. 20. A record of Case X showing an extremely sudden initiation of a series of oscillations. Before the repetition of each ɔ sound the stutterer inspired sharply to produce the breathy, extremely suddenly initiated tone seen here.

consisted of attempting to speak on inhalation. Another unusual feature recorded in this figure was the relatively isolated complex wave or series of oscillations at the end of the tone.

(e) Abnormal Endings of Tones in Stuttering

Inasmuch as the release of a tone involves as much of an active process as does the attack of a tone one would expect to find in the stutterer abnormalities in the former as well as in the latter.

In our records of the vocal disturbances in stuttering this expectation was realized in all cases.

A relatively common atypical ending of a tone is presented in Fig. 21. Clinically the stutterer was spasmodically repeating ɔ as in " all " in an attempt to give the name of his home town which began with *l*. The waves marked A, B, C, D, and E varied one

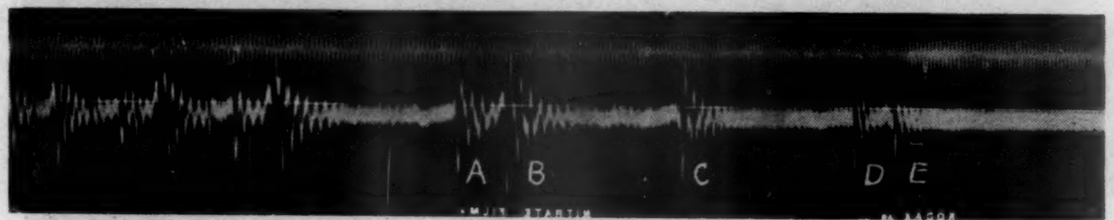

FIG. 21. A record of Case IV showing a common atypical ending of a stuttering tone. The stutterer was spasmodically repeating ɔ in an attempt to say a word beginning with " *l* ".

from the other in form, intensity, and length. A and B as well as D and E could have been one wave. Even if this were true, their remarked differences still remained.

A very common atypical ending of a tone in stuttering was revealed in Fig. 22. The tone was ended with an escape of breath

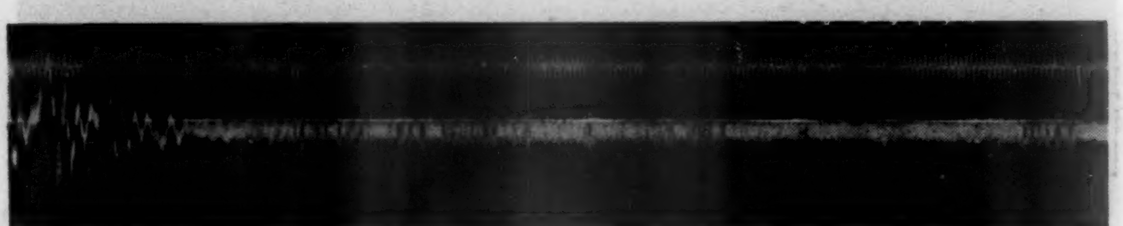

FIG. 22. A record of Case IV showing a second common variety of atypical ending of a stuttering tone. The stutterer's difficulty made it impossible for him to finish the word " correction " with the result that the word was ended with a sibilant instead of with the nasalized tone *n*.

which persisted for a considerable fraction of a second. The stutterer was experiencing difficulty with the word " correction ". His speech trouble made it impossible for him to finish the word with the result that it ended with a sibilant instead of with a nasalized tone *n*. This same phenomenon was very frequently seen between tones in stuttering (Fig. 23). When it was so encountered it was difficult to decide whether it was related to the beginning or ending of tones. In this particular record (Fig. 23) the stutterer was producing ə. This sibilant production also

occurred so relatively far removed from either a beginning or ending of a tone as to be considered an isolated phenomenon (Fig. 24). Such isolated productions were usually initiated by extremely sharp high frequency oscillations. Aperiodic variations in the intensity of the vibrations occurred throughout such

FIG. 23. A record of Case IV showing the same phenomenon mentioned in FIG. 22 to occur between tones. The subject was stuttering on ə.

records. The length of these sibilant productions varied. It ranged from .012 sec. to .111 sec. In the particular record shown in Fig. 24 the stutterer was attempting to say " thread ". His recorded difficulty consisted of a type of fricative sound resembling *t*.

FIG. 24. A record of Case XVI showing the phenomenon mentioned in FIGS. 22 and 23 to occur as an isolated series of high frequency oscillations. The stutterer was attempting to say " thread ".

(f) Normal Tones

For purposes of comparison two normal tones, one of a normal speaker and the other of a stutterer, are included in Figs. 25 and 26. The following characteristics are to be noted: (1) a gradual, even increase in the extent of the beginning voice waves; (2) a gradual, even decrease in the extent of the ending voice waves; (3) gradual and relatively small changes in length and form of consecutive waves; and (4) absence of any waves with bizarre forms (highly damped, breathy). The great majority of tones

during stuttering did not present all of these characteristics; a great many did not possess any.

(g) Further Noted Irregularities in Stuttering Tones

There were a number of definite abnormalities in tones during stuttering that did not fall into any of the larger groups we have discussed. They appeared with such consistency in stuttering

FIG. 25. A record of a tone of a normal speaker.

records that a study of the vocal disturbances of stutterers would be incomplete if no mention were made of them.

It has been known for a long time that stutterers frequently attempt to speak on inhalation. Records of breathing during stuttering (14, 3) showed that such attempts may persist for

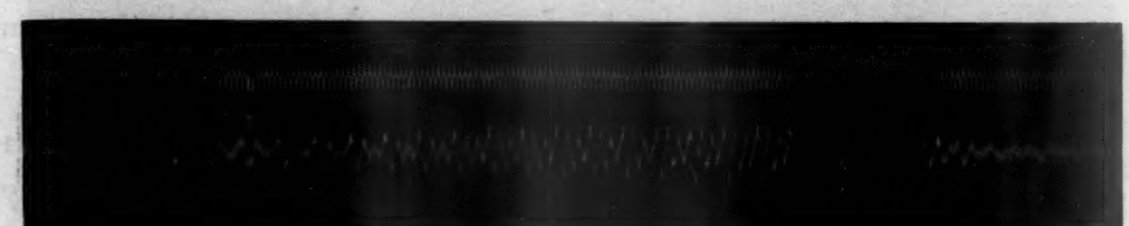

FIG. 26. A record of a normal tone of Case XIV.

relatively long intervals of time. During such inhalatory speaking efforts vocalization may or may not occur. In the present study we were fortunate to obtain records of vocalizations on inhalation for five of our stutterers. Fig. 27 is such a record. Clinically the stutterer's vocal production resembled the sound I. In this record we noted marked variations in the length, form, and size of consecutive waves. Practically no two consecutive waves were similar in form, a feature characteristic of noise. From the standpoint of vocal physiology such productions may be considered as indicative of a striking lack of integration in the vocal

mechanism. Not only does this mechanism appear to lack unity in its own parts but it does not appear to be integrated with respect to the breathing mechanism to effect normal vocalization on the outgoing breath stream.

Another symptom of stuttering which not only has been known for a long time but which has afforded one support for a certain theory of stuttering is the production of sucking movements in attempts to speak. Sucking may have characteristic sound qualities. In our phonophotographic records of stuttering it consisted in the main of aperiodic variations in the intensity of high frequency oscillations (Fig. 28) which was found in 10 cases. We may think of this record and similar ones (Figs. 15, 16, 23, and 24) as presenting a form of modulated wave which is made up of a relatively high frequency (1500 per sec.) and a lower

FIG. 27. A record of Case I showing vocalizations on inhalation. Clinically the stutterer's production resembled the sound I.

frequency (200 to 400 per sec.). The latter frequency is composed of variations in the intensity of the former frequency. From such an analysis it seemed reasonably safe to assume that there were at least two frequency sources. One source was responsible for the high frequency oscillations and the other for the modifications in the intensity of these oscillations. The former was probably due to the rushing of the inspired breath through the air inlet which must have been of extremely small dimensions. The other was probably due to extremely short and sudden activities on the parts of the articulatory structures (lips, tongue). All voluntary attempts on the part of both normal speakers and stutterers have failed to produce the clearly marked extremely rapid fluctuations in the intensity of the high frequency oscillations (Fig. 29). Generally they resulted in a single group of high frequency oscillations lasting not less than .033 sec.

Travis (13) reported periodic fluctuations of breath pressure just before, between, and immediately after tones in the stutterer's speech. These pulsations occurred at a rate varying between 25 and 30 per sec. A number of our records revealed a similar phenomenon (Fig. 30). However, some of *Travis'* records showed the pulsations to be represented by relatively

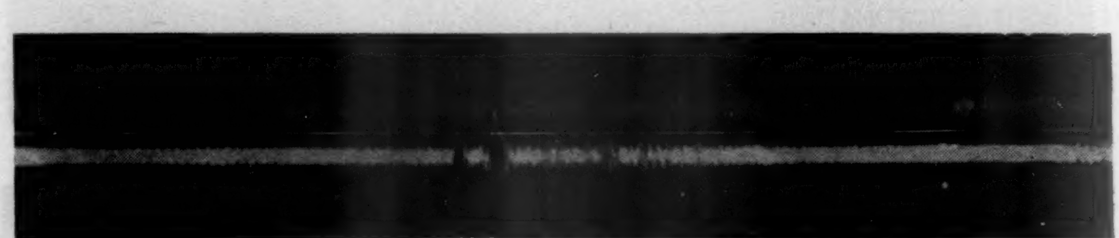

FIG. 28. A record of Case XVI showing sucking.

smooth sine waves whereas all of our records pictured them as made up of high frequency oscillations. Each group of oscillations was initiated extremely suddenly. Clinically the stutterer was attempting to say " special delivery ". With his lips and jaws slightly parted he appeared to be panting very rapidly. In

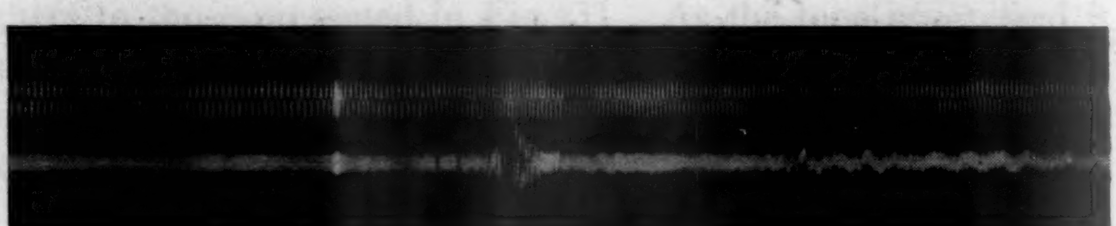

FIG. 29. A record of a normal speaker's production of sucking (*cf.* FIG. 28).

general the rate of the groups of oscillations varied from 30 to 75 per sec. Before tones there was a tendency for them to increase in their rate of appearance. This tendency is noted in Fig. 30. The intervals of time between the successive groups were as follows: .034, .029, .032, .025, .022, .029, .019 and .012 sec. In terms of frequency the range would be from 33 to 83 per sec. *Hill* (6) has recorded tremors in voluntary muscular contraction at a rate of 40 to 50 per sec. *Travis* and *Hunter* (15) have recorded such tremors at a rate as high as 200 per sec. Particularly pertinent to this specific stuttering phenomenon is the observation made by *Herren* (5). He found that stutterers, much more consistently than normal speakers, presented a pre-

ponderance of tremors at a rate of from 40 to 75 per sec. during increased voluntary effort. Records such as those in Fig. 30 represent ineffectual efforts on the part of the stutterer to say a given word. Success may follow immediately upon the termination of such effort. It may not have come until after a considerable fraction of a second of apparently complete absence of stuttering activity.

FIG. 30. A record of Case XVI showing pulsations in the outgoing breath stream. The stutterer was attempting to say "special delivery".

A somewhat similar phenomenon in stuttering is presented in Fig. 31 which occurred in six cases. In this instance, however, the stutterer in the midst of saying the word "delivery" presented a certain type of unusual vocalization between the first and second syllables. It consisted of extremely slow voice waves

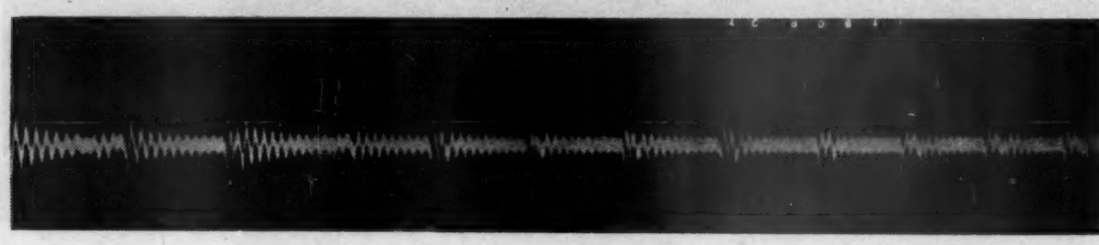

FIG. 31. A record of Case XVI showing an extremely low-pitched tone (50 voice waves per sec.). The stutterer was saying the word "delivery".

(50 per sec.) which vary considerably in form and extent. The low frequency is noteworthy. The pitch of the voice when speaking varies with different individuals, ranging from about 90 ~ per sec. for a deep-voiced man to about 300 ~ per sec. for a shrill-voiced woman. In normal speech our male stutterer possessed a voice of average pitch. This implied that during the recorded vocal disturbance the vocal cords must have been in a state of pathologic flaccidity. This disturbance although more frequently encountered as we have noted it here may occur at the end of a stuttering tone.

An extremely interesting record of vocal disturbances in stuttering is shown in Fig. 32 (A and B). The stutterer was trying to repeat *a* as in " father ". The beginning waves were pathologically slow having been similar in this respect as well as in

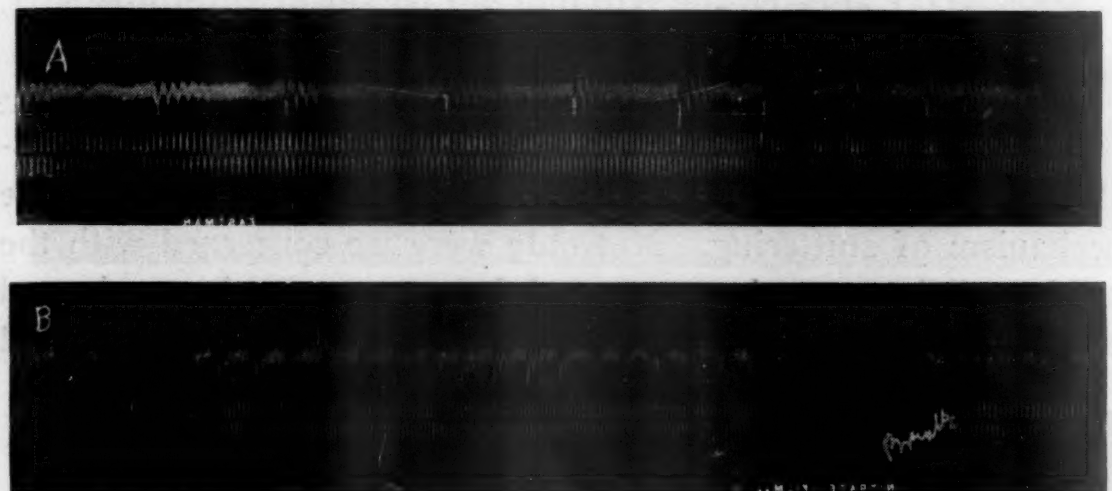

Fig. 32. (A and B) A record of Case XIII showing a progression through pathologically slow waves into extremely high oscillations indicative of hissing. The stutterer was attempting to repeat (a) as in " father ". A and B are one record.

others to those presented in Fig. 31. As the tone progressed it presented waves of higher and higher frequency until it finally ended in high frequency oscillations denoting hissing. There is here an indication of progression through flaccidity into rigidity

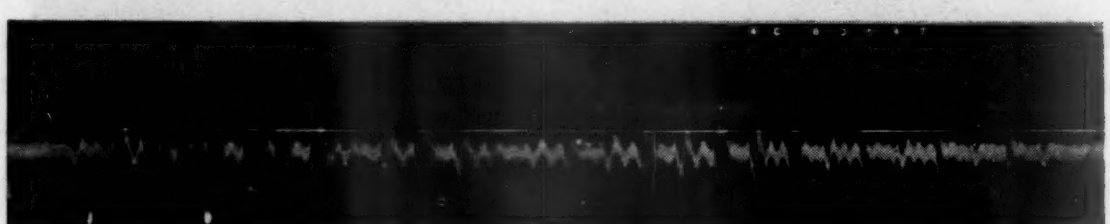

Fig. 33. A record of Case XVI showing marked variations in the form, extent, and length of consecutive waves. The stutterer was producing the sound æ as in " tap ".

suggestively similar to the transition from clonic reflex movements into tetanic contractions as reported by *Cobb* (1).

An instructive record is presented in Fig. 33. The stutterer was actually producing æ as in " tap ". This tone should be compared with that in Fig. 34 which presents æ as produced by a normal male speaker and with the records of this sound reported

by *Crandall* (2). In contrast to the normal speaker's tone the stutterer's tone showed marked variations in the form, extent, and length of consecutive waves.

(h) Attempts to Change Involuntary Stuttering Spasms to Voluntary Spasms

The relation of " volition " to stuttering has often been mentioned in the literature. We were interested here in such a possible relationship only so far as it might have shed light upon the mechanism of stuttering. Not only were we concerned with the striking differences that appeared between normal speech and stuttering but in the question of whether the stutterer could

FIG. 34. A normal speaker's production of æ in contrast with FIG. 33.

control his stuttering movements to the degree that they became strictly volitional in nature. In order partially to answer this question we required our stutterers to continue voluntarily the movements which began involuntarily as stuttering. Several fairly well established points resulted from this phase of the inquiry. One was that a number of our subjects were never able and none of our subjects were always able to gain voluntary control over their stuttering movements, *i.e.*, they could not change at will the involuntary spasms to voluntarily produced imitative ones. For those stutterers who were able at times to imitate their stuttering spasms, more frequently than not, their voluntary efforts sooner or later were interrupted by, or replaced with, true stuttering spasms. This fact was not only repeatedly indicated clinically but was amply demonstrated in our photographic records of the stutterer's voluntary efforts to reproduce his stuttering movements. Practically all of the vocal disturbances discussed in earlier parts of this study appeared in records of our stutterers' voluntarily produced speech difficulties. This did not

mean that they were able to voluntarily produce the variously recorded vocal disturbances such as marked variations in the intensity, form, and length of consecutive waves, abnormal tonal attacks and endings, isolated waves, *etc.* Rather it meant that true stuttering displaced the imitative movements. The clinically

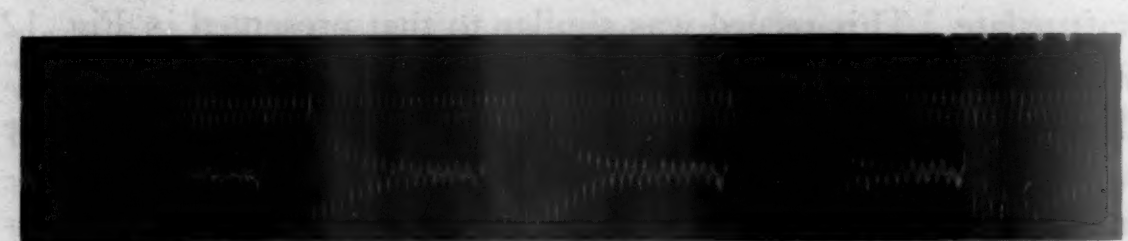

FIG. 35. A normal speaker's production of an inhalatory "snore" (*cf.* FIG. 5).

successful imitative stuttering movements were in reality very dissimilar photographically to the real stuttering movements.

To throw additional light upon our records of vocal disturbances during stuttering we required a number of trained normal speakers to produce a wide variety of sounds and noises. In the production of some of these the subjects have performed in very

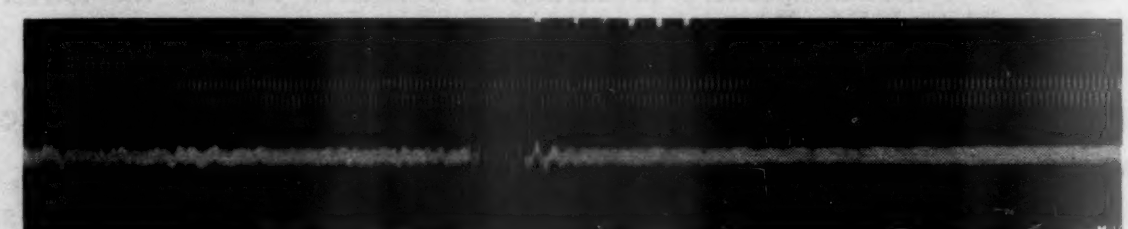

FIG. 36. A normal speaker's production of a noise characteristic of the tree squirrel (*cf.* FIG. 12).

unusual ways. Particularly three records from this phase of the study seemed to help clarify our concepts of what some of the stuttering records mean.

Fig. 35 bears a striking resemblance to Fig. 5, the main difference being that the variations in consecutive wave lengths were much more striking in the latter than in the former. In Fig. 35 the normal speaker was producing a sustained inhalatory snore and in the record of which Fig. 5 is a part, the stutterer was producing a sound resembling *a* as in "father". On the basis of phonophotography it appears that in the particular part of the record shown in Fig. 5 the stutterer's vocal effort resulted in a

snore. We might conclude that the snore "broke into" the *a* sound.

In Fig. 36 the normal speaker was making a noise similar to that characteristic of tree squirrels. It was produced by having the back of the tongue suddenly released from contact with the soft palate. This record was similar to that presented in Fig. 12 which shows the results of a stutterer's effort to say "question". The subject was actually repeating *k*. In his repetitions there appeared a characteristic wave (A) before each series of vocalizations (initiated at B). The sharp waves (B) indicated additional vocal disturbances. The striking similarity between the normal speaker's record and part A of the stutterer's record indicated that the vocal disturbances of the stutterer might have

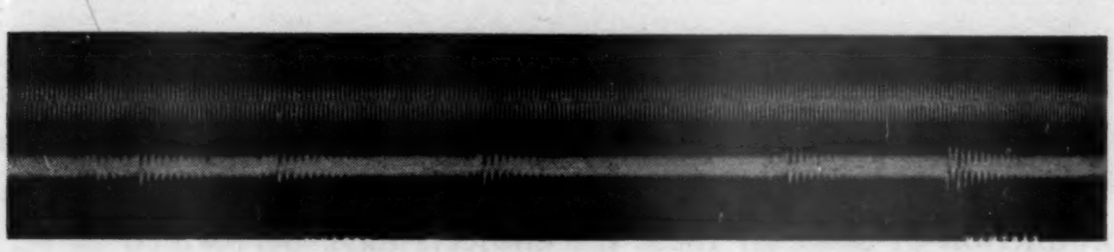

FIG. 37. A normal speaker's production of a relaxed tone of the lowest pitch possible (*cf.* FIG. 31).

been the result of an unwittingly produced tongue and palate action.

For the record presented in Fig. 37 the normal speaker was producing a relaxed tone of the lowest pitch possible. One would judge that the vocal bands were extremely flaccid and only slightly approximated. This record bore a striking similarity to that of a stutterer presented in Fig. 31. The photographic resemblance noted here supported the clinical observations that the stutterer, in his attempts to say a word, was interrupted by the initiation of an extremely relaxed, flaccid condition of the vocal mechanism.

V. Conclusions. Because we were not able completely to penetrate the meaning of our recorded vocal disturbances, scientifically we should not be too exhaustive either in a physical or a physiological interpretation of them. Certain seemingly clearly defined facts stand out, however, as meaningful. To these we may now turn our attention.

Generally considered, throughout the most of our records there is indicated an element of suddenness of change and uncertainty of execution in physiological activity. In records of normal speaking voices smoothly flowing, rhythmical activity is the indicated characteristic action of the voco-motor mechanism. The marked variations in the form, extent, and length of consecutive waves and the appearance of isolated waves in this study attest to the truth of the former statement. These phenomena not only did not occur in the records of normal speech but they could not be duplicated voluntarily by either the stutterer or the normal speaker. Some of the recorded changes in physiological activity, at least in physical activity, begin and end within .0018 sec. The abnormality would appear to consist of extremely sudden interference with, or disturbance of, the functional relationships between different parts of the vocal mechanism obtaining at the time the change occurred. An entirely foreign type of integration (dysintegration) seemed to have been interjected. Further uncertainty of action was seen in the unusual attacks and endings of tones.

A type of activity which is the antithesis of change was seen in those tones of extreme rigidity. The variation in pitch which is characteristic of the normal tone indicated that in the normal person there occur alterations of the fixed muscular tension which would be requisite for the maintenance of a tone of absolutely constant pitch. The absence of such variations, therefore, especially for the lengths of time recorded in many of our records, is to be considered as pathologic. The abnormality would seem to consist of marked fixation on the part of those muscles that have to do with altering the tension of the vocal bands, so that the muscular balance necessary for tone production is for some reason or other maintained in a condition of rigidity that is pathologic. This condition was the more striking when it is recalled that in every instance of such tonal rigidity the stutterer was attempting to release the tone. Thus again we have evidence of an active interference with the integrative process characteristic of normal speech.

VI. Summary. Phonophotographic records of the stutterer's

voice during stuttering showed the following: (1) marked variations in the form, length, and intensity of consecutive waves: (2) extreme tonal rigidity; (3) a variety of isolated waves; (4) a variety of abnormal attacks of tones; (5) a variety of abnormal endings of tones; (6) a form of vocalization on inhalation; (7) informative sucking and snoring noises; and (8) pulsations in the breath stream before, between, and after tones.

Photographic records of the stutterer's attempts to change real stuttering into voluntarily produced imitative movements of it showed all of the phenomena listed above. Photographically considered the normal speaker was unable to stutter successfully.

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AN ACTION CURRENT AND REFLEX TIME STUDY OF PSYCHIATRIC AND NEUROLOGIC CASES

by

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I. Introduction. The introduction of the electromyographic method into investigations of muscular and nervous activity has served to stimulate a large field of research. It furnished a more refined technique with which to attack existing problems and broadened the field which became amenable to experimental treatment. The lever system with its large amount of inertia was replaced by apparatus which was relatively free from this source of error.

Among the earliest investigators to apply this new technique to the measurement of reflex time were *Snyder* (1) and *Hoffmann* (2). Each used two subjects and found that the reflex time of normal individuals varied from .008 to .024 sec. More recently there have been several extended investigations of the reflex time of normal individuals. *Travis* and *Young* (3) determined the patellar tendon reflex times of 122 normal college students, and found the average to be .0197 sec. They also found that there was not only a relatively high correlation between height and reflex time amounting to $.73 \pm .029$, but that this correlation was higher than that between reflex time and measures designed to be truer functions of the length of the peripheral arc. Thus, in comparing the reflex times of two or more individuals, their separate heights must be taken into consideration. For this purpose the authors suggested the use of the ratio of height in cm. to reflex time in σ. In terms of H/T they found the mean of the normal group to be 8.76 and the S.D. of the distribution to be .390.

Whitehorn and *Lundholm* (4) determined the reflex times of 57 normal individuals and found that the correlation with height

amounted to .76±.038. They found further that the average difference between the patellar tendon reflex time of the right leg and that of the left amounted to .06 σ, a difference well within the limits of the experimental error. For all practical purposes it may be assumed from their study that the patellar tendon reflex times on the right and left sides of the normal individual are the same.

From the above investigations in which a total of 179 normal subjects were used, it may be concluded that the reflex time of the normal individual is determined, to a large extent, by the length of the arc involved, the best criterion of which is height. The variability of reflex times due to the action of other factors can not, therefore, be disclosed until the influence of height is equalized as far as possible.

Hoffmann (2) was the first to record (Achilles) reflex times in patients with physical or mental aberrations. He found that in comparison with normals his patients as a group presented slower conduction rates and longer reflex times. He explained this on the basis of a decrease in the conduction rate of the impulse through the reflex arc.

In 1928 *Travis* (5) determined the reflex time of a cataleptic patient and found it extremely short during the early phase of the condition, .0059 sec. This progressively lengthened during the course of convalescence until at the time of discharge it was .0185 sec. Following this *Travis* and *Dorsey* (6) investigated the effect of alcohol upon the patellar tendon reflex time. They found that as the alcoholic stupor progressed the reflex time decreased and as the stupor cleared the reflex time increased. It was inferred from this evidence that as the inhibitory activity of the higher centers is reduced through the action of the alcohol, the rapidity of the activity of the lower centers becomes relatively increased.

Supporting evidence for the above inferences was secured by the same authors (7) in a later study in which the reflex times in several psychiatric and neurologic cases were determined. They found that as the activity of the higher centers was increased, as in the manic phase of a manic-depressive psychosis, the rate of

the reaction of the lower centers was decreased and a longer reflex time followed. Furthermore, when the activity of the higher inhibitory centers was decreased, as in a catatonic state of a toxic-infective-exhaustive psychosis, the rapidity of reaction of the lower centers was relatively increased and a shorter reflex time resulted. This evidence seems to indicate rather definitely that the higher cortical centers dominate the activity of the lower centers and that a hyper- or hypo-activity of the former results in a hypo- or hyper-activity of the latter.

The present investigation was designed to determine whether this relationship between higher and lower centers was similarly modified in a wider variety of psychiatric and neurologic cases. For this purpose a number of unselected cases were used, representing both the organic and the so-called functional types of disorder. Not only were the reflex times determined, but records of the action currents incident to the voluntary contraction of the muscle group involved in the reflex contraction were secured. This permitted a comparison of both the gross qualitative and quantitative features of the action currents produced by voluntary and reflex innervation.

II. Apparatus and method. The apparatus used in this experiment has been fully described by *Travis* and *Hunter* (8) and *Travis* and *Lindsley* (9). Briefly, it consisted of a three stage resistance-coupled amplifier, used in connection with a Westinghouse three element portable oscillograph. A time line was secured through the use of a General Radio Company low frequency oscillator, operating at a frequency of 1,000 ~ per sec. To make possible the determination of the latent time of the reflex, the instant of stimulation was recorded by the use of a circuit in which the stimulus discharged a previously charged condenser. The latent time is then considered to be the interval elapsing between the instant of stimulation and the arrival of the first action currents produced in the muscular contraction. These records were photographed on Eastman 35 mm. motion picture film.

Silver plated brass electrodes, 1.3 x 3.5 cm., were used. These were covered with canton flannel, which was soaked in saturated

salt solution to insure adequate contact with the skin. They were placed six to eight mm. apart on the quadriceps femoris muscle at a point midway between the anterior superior spine of the ilium and the upper border of the patella. *Tuttle* and *MacEwen* (10) found that this is a relatively constant position of the point of entrance of the motor nerve into the muscle involved in the reflex contraction. Records of the action currents during voluntary movement were secured with the electrodes similarly located.

The subjects were seated with one thigh slightly raised to insure both freedom of movement and slight tension of the muscle involved. Attached over the tendon was a small brass strip which, when struck with a small iron mallet, actuated the signal circuit. After the electrodes were located and the apparatus checked a series of five or more reflex records were photographed. As it had been previously shown by *Tuttle* (11) and *Travis* and *Young* (3) that the strength of the stimulus does not materially affect the reflex time, the strength of the blow was varied from subject to subject, depending on the ease with which the reflexes could be elicited. In securing records of voluntary movement the subjects were requested to raise and lower the leg at a given signal and according to a definite plan. The signal was given after the camera was started to insure the photographing of the entire extension movement. The leg was elevated to the horizontal plane.

Records from both the right and the left sides were secured in those cases which gave evidences of asymmetrical neuromuscular disturbances. This was done in an attempt to find indications of differences in innervation or control of the two sides expressed in terms of a modification of either reflex time, action current frequency, or some qualitative features of the discharges.

III. Cases. A total of 66 individuals were used, a majority of whom were patients in the Psychopathic Hospital of the University of Iowa. The remainder were patients in either the Neurological Department of the General Hospital or the Orthopedic Department of the Children's Hospital. Briefly, the patients fell into the following classifications:

Diagnosis	No. of cases
Psychoneurosis	19
Schizophrenia and dementia praecox	10
Paranoid state	5
General paralysis	3
Syphilis of the central nervous system	2
Aphasia	3
Hypothyroidism	3
Hyperthyroidism	1
Multiple sclerosis	2
Sclerosis, amyotrophic lateral	1
Traumatic psychosis	2
Manic-depressive psychosis	2
Encephalitis	1
Encephalitis, post	2
Spastic paralysis	2
Parkinson's syndrome	1
Huntington's chorea	1
Psychosis with cerebral embolism	1
Psychosis with somatic disease	1
Psychosis in an epileptic personality	1
Involutional melancholia	1
Moronism with psychosis	1
Psychopathic personality with hypomanic episodes	1
Undiagnosed	1

IV. Results. The results of the present investigation are summarized in Table I. The reflex time as given is the average of all reflexes secured from the subject, usually five or more. In the determination of reflex frequency the number of peaks, regardless of their extent, in the action current discharge was counted throughout the entire duration of the volley and the frequency per sec. calculated from the result. In the determination of the frequency of the action currents during voluntary contraction the number of peaks occurring during five to eight consecutive .01 sec. intervals was counted and the frequency per sec. was calculated from the average of these readings. No differentiation was made between the so-called primary and secondary waves (Nebenzachen) except in qualitative notes on several of the cases.

TABLE I.* *Reflex times, H/T values, and reflex and voluntary action current frequencies for 66 psychiatric and neurologic cases*

Case No.	Diagnosis	Reflex time	H/T	Reflex frequency	Voluntary frequency
1.	Psychoneurosis, hysteria	21.2	8.18		
13.	Psychoneurosis, hysteria	21.5	7.80		512
16.	Psychoneurosis, hysteria				440
24.	Psychoneurosis, hysteria	22.25	8.44		665
31.	Psychoneurosis, hysteria	21.0	8.17		633
37.	Psychoneurosis, hysteria	19.0	8.49		

TABLE I—*Continued*

Case No.	Diagnosis	Reflex time	H/T	Reflex frequency	Voluntary frequency
44.	Psychoneurosis, hysteria	19.5	9.06	666	575
48.	Psychoneurosis, hysteria	18.1	8.98	507	500
50.	Psychoneurosis, hysteria	17.2	9.53		
60.	Psychoneurosis, hysteria	20.2	7.92	333	500
66.	Psychoneurosis, hysteria	17.8	9.13		
72.	Psychoneurosis, hysteria	18.75	7.86		407
6.	Psychoneurosis, psychasthenia.	20.0	7.71		
2.	Psychoneurosis, neurasthenia..	18.9	8.53		
45.	Psychoneurosis, anxiety type..	20.3	8.93	550	628
7.	Psychoneurosis, mixed type...	16.9	8.83	334	
68.	Psychoneurosis	20.5	8.41		
69.	Psychoneurosis	20.5	9.04	333	512
70.	Psychoneurosis	17.9	9.33	456	
8.	Schizophrenia	18.6	8.40	437	
53.	Dementia praecox, simple.....				612
47.	Schizophrenia, hebephrenic....	19.8	8.53	580	550
35.	Dementia praecox, hebephrenic	18.1	8.98		
65.	Dementia praecox, catatonic...	20.5	7.93		
22.	Schizophrenia, paranoid.......	21.0	8.22		602
20.	Schizophrenia, paranoid.......	17.3	9.51		625
61.	Dementia praecox, paranoid...	21.8	8.43		570
58.	Dementia praecox, paranoid...	22.8	8.17		
73.	Dementia praecox, paranoid...	19.25	8.58		500
42.	Paranoid state	17.5	9.51	502	
25.	Paranoid state	24.0	7.25		
49.	Paranoid state	19.6	8.42	574	600
54.	Paranoid state	17.25	10.75		596
46.	Paranoid state	17.5	10.65	565	525
11.	General paralysis	23.3	7.25		
15.	General paralysis	17.2	9.74	484	552
39.	General paralysis	18.25	8.49	483	574
74.	Syphilis of the central nervous system ....(R)	16.5	10.31		490
	(L)	18.0	9.45		467
64.	Neuro-syphilis, meningo-vascular type ....(R)				725
	(L)	20.6	8.33		695
10.	Aphasia	15.5	8.85	304	477
18.	Aphasia ....(1st-R)	21.5	8.38		622
	(1st-L)	23.5	7.67		
	(2nd-R)	21.7	8.31		603
	(2nd-L)				545
23.	Aphasia ....(R)	21.1	7.41		625
	(L)	20.3	7.69		612
29.	Myxedema	22.7	7.05		682
30.	Myxedema	22.25	7.93		604
34.	Hypothyroidism	18.1	9.12		695
19.	Hyperthyroidism				597
55.	Multiple sclerosis ....(R)	22.4	7.71		570
	(L)	13.25	13.04		583
56.	Multiple sclerosis ....(R)	19.5	8.17	648	600
	(L)	20.0	7.97	584	595
63.	Sclerosis, amyotrophic lateral (R)	20.1	8.38	351	
	(L)	20.0	8.42	317	590

TABLE I—*Continued*

Case No.	Diagnosis	Reflex time	H/T	Reflex frequency	Voluntary frequency
28.	Traumatic psychosis... (1st–R)	22.6	7.87		527
	(1st–L)	22.8	7.80		585
	(2nd–R)				545
	(2nd–L)				517
52.	Traumatic psychosis	17.5	9.80		593
12.	Manic-depressive, depression (1st)	20.6	9.09		
	(2nd)	22.0	8.51	445	447
40.	Manic-depressive, hypomanic..	21.8	7.55		650
32.	Encephalitis, Parkinsonian syndrome................(R)	20.25	8.09		645
	(L)	17.5	9.36		620
21.	Post-encephalitic syndrome (R)	18.8	9.33	511	610
	(L)	17.3	9.06	533	590
62.	Spastic paralysis ....(R)	16.0	9.92		635
	(L)	17.0	9.34		620
14.	Cerebral spastic paralysis, motor aphasia	14.8	8.75	349	483
67.	Parkinson's syndrome				623
5.	Huntington's chorea	18.8	8.18		
33.	Psychosis with cerebral embolism................(R)	19.6	8.10		
	(L)	19.6	8.10		
17.	Psychosis with somatic disease				497
41.	Psychosis in an epileptic personality.................				500
36.	Involutional melancholia	20.2	8.05		626
27.	Moronism with psychosis (1st)	20.7	7.92		
	(2nd)	20.7	7.92		
4.	Psychopathic personality with hypomanic episodes	20.4	8.78	391	
71.	Undiagnosed...............	19.75	8.02	316	455

* The reflex time is given in σ. H/T is the quotient of the height of the individual in cm. divided by the reflex time in σ. Reflex frequency is the frequency per sec. of the action currents recorded during the reflex contraction of the quadriceps femoris muscle. Voluntary frequency is the frequency per sec. of the action currents recorded during the voluntary contraction of the quadriceps femoris muscle. R and L indicate records from the right and left sides, and 1st and 2nd indicate results obtained on two different occasions.

The mean, the range and the S.D. of the H/T values: For the entire group of subjects used in the present investigation the mean H/T value is 8.60 in a range of 7.05 to 13.04. The S.D. of the distribution of H/T values is .903. In comparing our results with those of *Travis* and *Young* (3) we find that our patients present a striking scatter of the reflex times. The general tendency of reflex times in cases with psychiatric or neurologic disorders seems to be away from the mean of the normal group. The fact that such a shift is not in one direction only is

indicated by the small difference between the mean of the normal (8.76) and that of the pathological group (8.60), but the presence of such a tendency is evidenced by the comparatively large S.D. of the H/T values of the latter group (.903 as compared to .390 for the normal group).

If grouped according to the organic or functional character of the disturbance the mean H/T value for the former group is 8.62, the range is from 7.05 to 13.04, and the S.D. is 1.08; the mean H/T value for the latter group is 8.50, the range is from 7.25 to 10.75 and the S.D. is .387. The significance of this comparison between organic and functional cases is confined almost solely to the much wider spread in the former. It appears that the alteration of reflex time is greater in organic cases than in the functional, with no marked tendency toward a general shift in either direction. A comparison, however, between similar groups in which the severity of the disorders were more comparable may necessitate a modification of this inference.

TABLE II. *A comparison of the functional groups*

Group	Mean H/T value	S.D. of H/T values	Range of H/T values	No. of cases
Normal........	8.76	.390	7.88– 9.33	122
Psychoneurotic..	8.57	.562	7.71– 9.53	18
Schizophrenic...	8.53	.397	7.93– 9.51	9
Paranoid.......	9.32	1.431	7.25–10.75	5

A division of the functional cases into the three groups, psychoneurotic, schizophrenic, and paranoid (Table II), shows that the mean H/T values and the S.D. of the H/T values of the first two do not vary significantly from each other or from the normal group. The paranoid group, however, presents a significantly greater mean H/T value (shorter mean reflex time) and a strikingly greater S.D. of the H/T values than does either the other two abnormal functional groups or the normal group.

In the 11 subjects with organic disorders, for which reflex times were determined on both the right and the left sides, it was found that although the differences in reflex times encountered on the two sides were usually small, they were significant (Table III). *Whitehorn* and *Lundholm* (4) found that the mean difference in patellar tendon reflex times of the right and the left

side of normal individuals is .06 σ. In our 11 organic cases such a mean difference is 1.68 σ.

From the evidence presented in Table III it may be inferred that in general the effect of an organic disturbance is bilaterally unequal. This is particularly significant in view of the fact that the cases did not present definite one-sided disturbances. From our limited number of cases, however, there is no clear evidence for selective susceptibility of either side to nervous diseases. Five cases presented a decreased reflex time on the right side; three cases presented a decreased reflex time on the left side; and three cases presented approximately equal reflex times on the two sides. A study of these results in relation to handedness is in prospect.

TABLE III. *A comparison of the reflex times on the right and on the left side of cases with lesions of the central nervous system*

Case No.	Diagnosis	Reflex Time (in σ) Right side	Left side	Relation of right to left
74.	Syphilis of the central nervous system	16.5	18.0	—1.5
18.	Aphasia	21.5	23.5	—2.0
23.	Aphasia	21.1	20.3	+.8
55.	Multiple sclerosis	22.4	13.25	+9.15
56.	Multiple sclerosis	19.5	20.0	—.5
63.	Sclerosis, amyotrophic lateral	20.1	20.0	+.1
28.	Traumatic psychosis	22.6	22.8	—.2
32.	Encephalitis	20.25	17.5	+2.75
21.	Post-encephalitis	16.8	17.3	—.5
62.	Spastic paralysis	16.0	17.0	—1.0
33.	Psychosis with cerebral embolism	19.6	19.6	.0
	Mean	19.67	19.02	1.68

Correlation between reflex time and height. A further indication of the scatter of the H/T values for our patients becomes apparent on examination of the correlation of reflex time and height. The investigations by *Travis* and *Young* (3) and *Whitehorn* and *Lundholm* (4) on normal individuals gave coefficients of .73±.029 and .76±.038 respectively. The reflex times of the psychiatric and neurologic cases in this study correlate only .46±.062 with height. The difference between the coefficient of correlation for the normal individuals and that for the abnormal group is statistically significant in that the actual difference is more than eight times its probable error in respect to the correlation in the first of the above mentioned investigations and more than six times its probable error in regard to the correlation of

the second of the above mentioned investigations. It may be inferred from this evidence that some factor, or factors, other than height, which is significant in the determination of reflex time, is inordinately effective or ineffective in psychiatric and neurologic cases.

The difference between the normal and the abnormal groups is the more striking in view of the fact that a large number of the psychiatric cases were convalescents. Of the total number of our cases only 10 were finally committed to state hospitals, although several others were discharged with an unfavorable prognosis or were recommended for commitment. Of those suffering from organic disturbances one died two weeks after the records were secured. Of the remainder, the majority were discharged as unimproved.

Variation in a single series of records. The variation found within a single series of records is important in this study, especially in view of the wide scatter of the reflex times secured from our group of cases. *Travis* and *Young* (3) determined the average of measures of variability within a single series of records for a group of 60 normal individuals. A comparison between the averages for the normal group and our group is made in Table IV.

TABLE IV. *Variations in σ in a single series of records*

Group	Greatest M. V.	Least M. V.	Average M. V.	Greatest range	Least range	Average range
Normal.......	.87	.00	.41	3.5	.0	1.6
Psychiatric and neurologic...	1.23	.00	.47	4.0	.0	1.4

It is apparent that a single series of reflex records secured from a psychiatric or a neurologic case presents practically the same degree of constancy as does a single series of similar records secured from a normal individual. This indicates that the changes in reflex time incident to psychiatric and neurologic disorders are not the result of moment to moment irregularities in the functioning of the nervous system. An actual alteration of factors or conditions is seen the expression of which in terms of reflex time is as nearly constant as is the expression in terms of reflex time of the regular balance of the nervous system of a normal individual.

Reflex and voluntary action current frequencies. Action currents during voluntary movement of the leg and during reflex activity were secured with the electrodes in the same position. This made it possible to compare reflex and voluntary action current frequencies from the same point on the same muscle. Using this same experimental arrangement with normal subjects *Travis* and *Lindsley* (9) found that the reflex action current frequencies were consistently greater than the voluntary action current frequencies. In 17 of our cases we were able to secure records of both reflex and voluntary action currents from the quadriceps femoris muscle (Table V). It is noted that the mean reflex action current frequency is less than the mean voluntary action current frequency. On the basis of the consistency of action current frequencies in any given record we have decided that a difference of 50 or more action currents per sec. is significant. Using this criterion it is apparent that 11 out of the 17 cases gave smaller reflex than voluntary action current frequencies, while only one case gave a greater reflex than voluntary action current frequency. These results are contrary to those obtained by *Travis* and *Lindsley* on normal individuals.

TABLE V. *A comparison of reflex and voluntary action current frequencies*

Case No.	Diagnosis	Frequency of reflex action currents	Frequency of voluntary action currents	Relation of reflex to voluntary frequency
44.	Hysteria	666	575	+91
48.	Hysteria	507	500	+7
60.	Hysteria	333	500	—167
45.	Anxiety neurosis	550	628	—78
69.	Psychoneurosis	333	512	—179
47.	Schizophrenia	580	550	+30
49.	Paranoid	574	600	—26
46.	Paranoid	565	525	+30
15.	General paralysis	484	552	—66
39.	General paralysis	483	574	—91
10.	Aphasia	304	477	—174
56.	Multiple sclerosis (R)	648	600	+48
	(L)	584	595	—11
63.	Sclerosis, amyotrophic lateral	317	590	—273
12.	Manic-depressive	445	447	—2
21.	Post-encephalitis (R)	511	610	—99
	(L)	533	590	—57
14.	Cerebral spastic paralysis	349	483	—134
71.	Undiagnosed	316	455	—139
	Mean	478	545	
	S. D.	118.1	61.2	
	Range	316–666	447–628	

Qualitative study of records. Interesting qualitative as well as quantitative results were obtained in many of our cases which gave indications of unusual trends in the group of subjects used in the present investigation. To serve as a basis of comparison for the records from psychiatric and neurologic patients which are cited on the following pages a typical reflex record secured from a normal individual is given in Fig. 1.

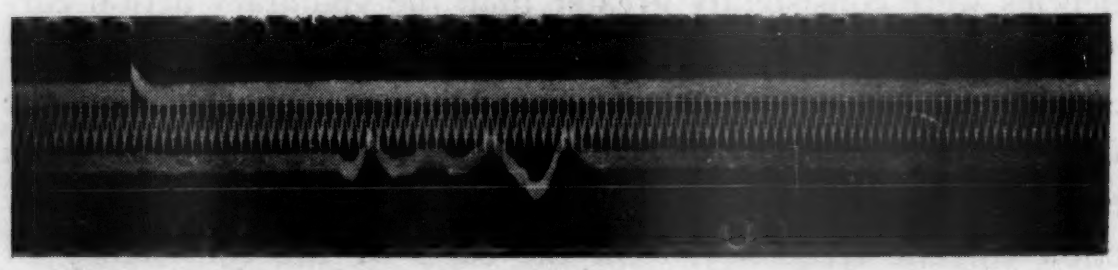

FIG. 1. Typical patellar tendon reflex record of a normal individual. The reflex time was read as 21.5 σ. The top line is the signal, the middle line indicates time in σ, and the lower line registers the action currents.

In Case No. 5 (Huntington's chorea) records were secured on three different occasions within one month's time and in none of these was a typical reflex record secured, but instead there appeared a consistently late discharge, 37.8 σ after the stimulus (Fig. 2). This late discharge volley presented action currents at

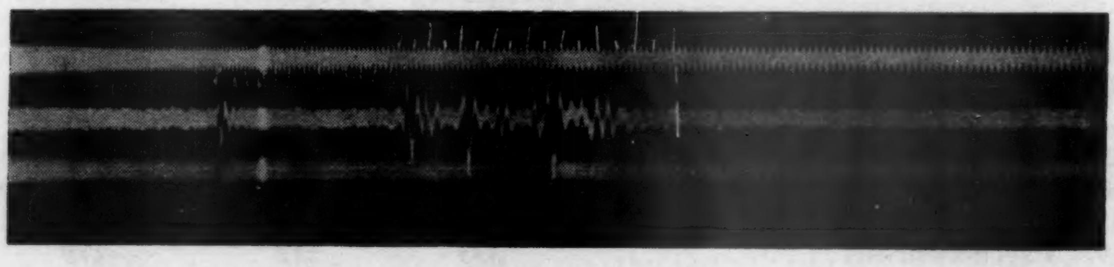

FIG. 2. Patellar tendon reflex record of Case No. 5 (Huntington's chorea). No typical reflex volley appears, but instead a late discharge occurs 38.5 σ after the stimulus. In this and the following few records the upper line shows time in σ, the middle line registers action currents and the lower line is the signal.

an average frequency of 598 per sec. In Fig. 2 the volley appears 39.0 σ after the stimulus and persists for a period of 49 σ with an action current frequency of 610 per sec. The consistency of the appearance of these discharges at a relatively constant interval after the stimulus, together with the fact that this interval is too short for a voluntary response, leads to the conclusion that it is a

reflex discharge which originates either in a different center or under different conditions than does the discharge which usually produces the muscular response in the knee-jerk.

Case No. 12 (manic-depressive psychosis, depression) showed a marked alteration of reflex time coincident with a change in the condition of the patient. At the time the first records were secured he was definitely depressed and somewhat confused. The reflex time was 20.6 σ with an H/T of 9.09. The second records were secured 41 days later, by which time he had become more cheerful and the confusion had disappeared. The reflex time was found to be 22.0 σ, with an H/T of 8.51. Thus a lengthening of reflex time of 1.4 σ occurred simultaneously with the disappearance of the symptoms of the depression. This is in line with the findings of *Dorsey* and *Travis* (12) that under-activity of the higher levels (depression) results in a relative decrease in reflex time.

From Case No. 14 (cerebral spastic paralysis with motor aphasia) records were secured which showed a continuous spasticity throughout with the exception of a short interval, averaging 15.7 σ in duration following the reflex discharge. The reflex volley was of much greater amplitude than were the action currents occurring during the spasticity. The records of the action currents during voluntary movement were marked by irregular alternate periods of predominately large waves of a frequency of 350 per sec. and of predominantly smaller waves of a frequency of approximately 600 per sec. The frequency calculated from a count of the total number of waves over a period of .8 sec. was 483.

In the records of the action currents during voluntary movement from Case 15 (general paresis), a periodic appearance of single or double diphasic waves was noted. The interval between these waves varied from 62.5 to 93.0 σ with an average of 81.4 σ. Since they do not appear in the reflex records and have a frequency approximating that of the normal tremor rate it seems possible that the waves were caused by the presence of a slight intention tremor.

In the reflex records secured from the left side of Case No. 18

(aphasia on the basis of cerebral hemorrhage) a period was found during which the records of the action currents did not present the usual superimposed small waves (Nebenzachen), but rather a sine wave form (Fig. 3). The amplitude of these waves was large with a marked periodicity in extent at a frequency of 44.5 per sec. The records of the action currents during voluntary movements of the left leg showed no periodicity with the usual presence of both large and small waves.

In Case No. 21 (no psychosis; post-encephalitic syndrome) there was a marked contraction of both platysma muscles with a drawing downward of the head and jaw during speaking. Action

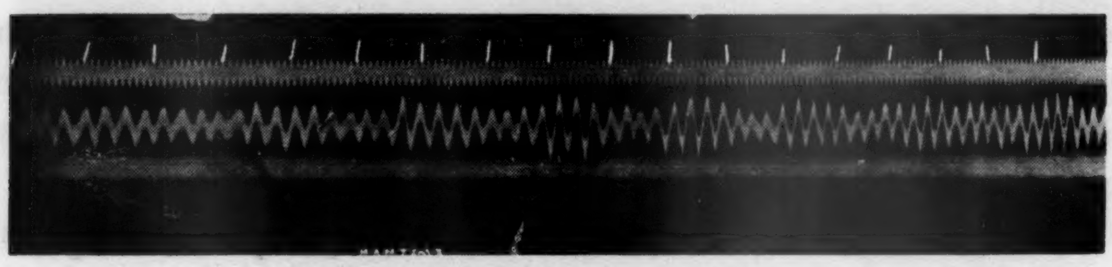

FIG. 3. Portion of patellar tendon reflex record of Case No. 18 (aphasia on the basis of cerebral hemorrhage) showing action currents with periodic fluctuations in extent at a frequency of 44.5 per sec. The total action current frequency was read as 375 per sec.

currents secured from the neck muscles during talking were characterized by large aperiodic discharges of a duration of about 5 σ. In the patient's attempt to reproduce voluntarily the jaw movements accompanying speech there resulted aperiodic action current volleys of extremely large intensity with a mean duration of 32 σ. The striking differences between the records obtained during the patient's customary contraction of the platysma muscles during speech and her voluntary imitation of such movements indicate that the source of the action current discharges are not the same in the two types of activity. Furthermore, in both her customary jaw movements and her imitation of these movements the action currents on the right were much larger than those on the left side of the neck. This is in line with the clinical finding that the tendon reflexes were larger and more prompt on the right than on the left side.

Portions of the record of voluntary movement of the left leg

of Case No. 32 (chronic epidemic encephalitis, Parkinsonian syndrome) showed action currents appearing in volley-like discharges at a rate of nine volleys per sec. with practically a complete absence of action currents between volleys. A single volley persisted on an average of 56.9 σ. The frequency of the action currents during these periods of discharge was approximately the same as during those portions of the record in which no periodicity was apparent.

Case No. 33 (psychosis with cerebral embolism) presented clinical findings which tended to localize the lesion in an area in the right cerebrum more directly related to the upper than the lower extremities. For example, the reflexes of the upper

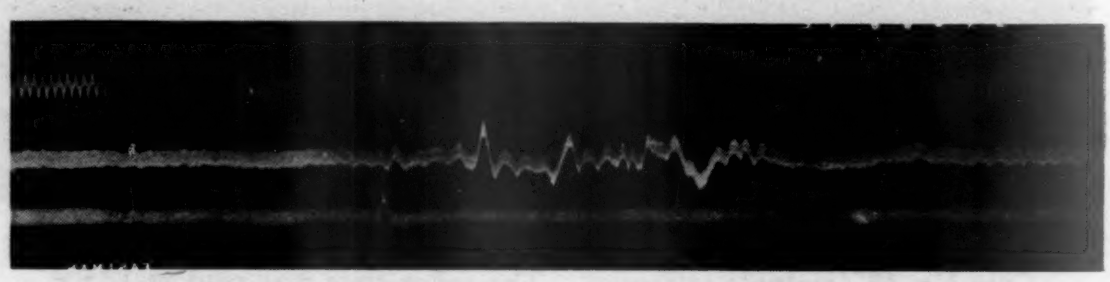

FIG. 4. Patellar tendon reflex time record from Case No. 44 (psychoneurosis, hysteria) showing a very early discharge.

extremities were more pronounced on the left than on the right side while those of the lower extremities were equally active and prompt. Our records of reflex time corroborated the clinical findings in revealing equal latencies in reflex response. We may interpret these findings to mean that the disturbance of relationship between higher and lower levels as determined by change in the patellar tendon reflex response latencies are dependent, to some extent at least, upon the locus as well as the age and extent of the lesion.

The reflex records obtained from Case No. 44 (psychoneurosis, hysteria) were marked by two extremely early discharges, one of which is reproduced in Fig. 4. These two early discharges were not included in the determination of the mean reflex time.

The reflex records secured from Case No. 45 (psychoneurosis, anxiety type) were marked by a consistently late discharge appearing 16 σ after the reflex volley proper, or 36.3 σ after the stimulus. The wave form of the action currents in the late

discharge was very constant, consisting of two or three diphasic waves, upon the first of which was superimposed one small wave. These late discharges averaged 8.9 σ in duration with an action current frequency of 450 per sec.

The records secured from Case No. 55 (multiple sclerosis) had several unusual features. The reflex time on the left side was 9 σ shorter than that on the right, and the respective action current wave forms were distinctly different (Fig. 5). The reflex volley on the right side was much less abrupt in appearance and followed more closely the typical wave form. In contrast to this the records of voluntary movement on the left side were

FIG. 5. Patellar tendon reflex time record secured from the left side of Case No. 55 (multiple sclerosis). The reflex time was read as 12.5 σ.

somewhat indistinct and of small amplitude while those on the right side were much larger. All of these findings indicate that the effect of the lesions was more pronounced on the right than on the left side of the brain. In records taken from the gastrocnemius muscle during an ankle clonus there were found periodic action current volleys at a rate of five per sec. Each volley persisted on the average 47.25 σ, with an action current frequency of 492 per sec. The periods between volleys were almost totally quiescent. In the voluntary imitation of the same movements the action currents were of approximately the same frequency, 508 per sec., but there was no periodicity of the action current volleys, there being instead a practically continuous action current activity.

Throughout the records of voluntary movement of the left leg and in records of both voluntary and reflex movements of the right leg of Case No. 56 (multiple sclerosis) there were aperiodic action current volleys. Each volley usually consisted of two or three diphasic waves. The intervals between consecutive volleys ranged from 18 σ to 125 σ in length.

In Case No. 62 (spastic paralysis) the reflex records on the right side were marked by very unusual periods of alternate discharge and quiescence following the stimulus. The averages of these readings are as follows: 27.4 σ after the stimulus a quiescent period was found with a duration of 23.6 σ, followed by a period of action current discharge with a duration of 13.4 σ which

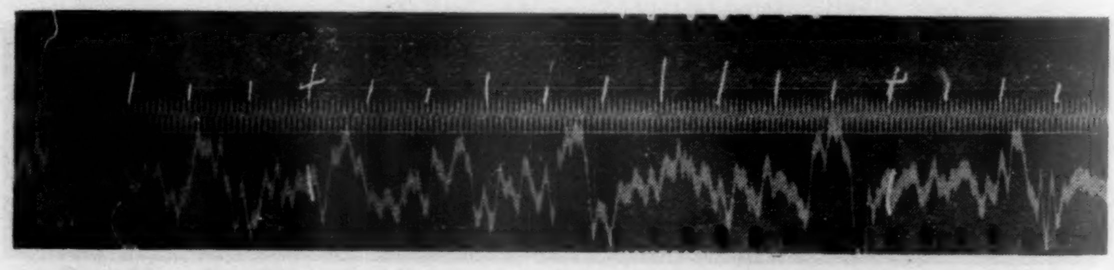

FIG. 6. Record of the action currents recorded during spastic contractions of the right forearm of Case No. 62 (spastic paralysis) showing large monophasic waves at a frequency of 41.5 per sec.

in turn was followed by another short period of quiescence prior to the recurrence of the spasticity. This latter quiescent period had a relatively constant duration of 13.2 σ except in one instance in which it continued for 31 σ. In the records of spastic contractions of the right forearm there appeared large monophasic

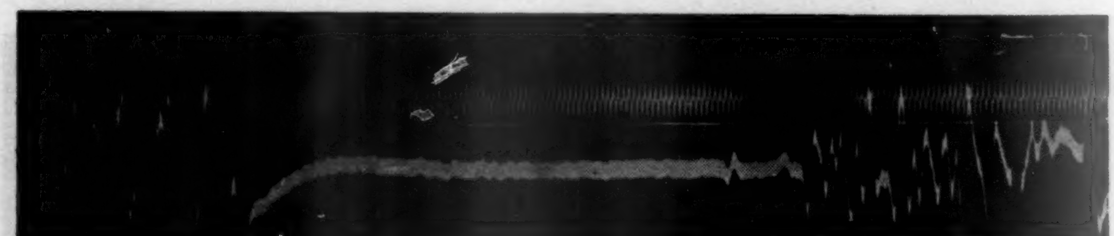

FIG. 7. Record of the action currents during a true clonus secured from the right gastrocnemius muscle of Case No. 63 (sclerosis, amyotrophic lateral).

action current waves with a frequency of approximately 41.5 per sec., upon which were superimposed smaller waves (Nebenzachen), bringing the total frequency to 630 per sec. (Fig. 6).

Case No. 63 (sclerosis, amyotrophic lateral) presented an ankle clonus, the action currents of which were recorded from the gastrocnemius muscle. The volleys were periodic, appearing approximately 6 times per sec. with periods of almost total quiescence between them. In the voluntary imitation of the same movements the action currents were continuous throughout with some observable though much less marked periodicity in their

extents. A record of the true clonus is shown in Fig. 7, while a portion of the record during the imitation of these clonic movements is reproduced in Fig. 8.

At the beginning of the records of action current activity during the voluntary movement of the right leg of Case No. 64 (neurosyphilis, meningo vascular type) there appeared periodic

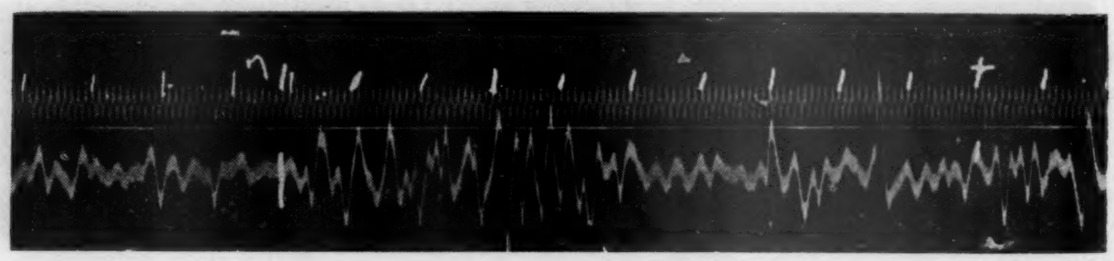

FIG. 8. Record of the action currents during the voluntary imitation of the clonus secured from the right gastrocnemius muscle of Case No. 63 (sclerosis, amyotrophic lateral).

changes in action current amplitude 112 times per sec. Toward the end of the same record were found action currents of large amplitude without the usual small waves superimposed on the larger ones, at an action current frequency of 670 per sec. (Fig. 9). The entire record secured from the right side was

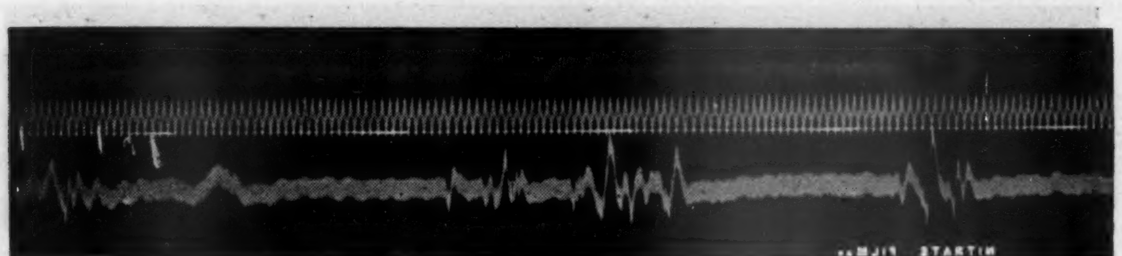

FIG. 9. Portion of the record of the action currents secured from Case No. 64 (neurosyphilis, meningo vascular type) showing aperiodic action current volleys. These volleys appear throughout the records of both reflex and voluntary movement.

marked by the presence of aperiodic volleys of extremely short duration. It appears from the record that these were caused by muscle twitches. A portion of this record is shown in Fig. 10.

In Case No. 67 (Parkinson's syndrome) no records of reflex volleys were obtained, but instead a constantly late discharge appeared 33.5 σ after the stimulus. One of these records is reproduced in Fig. 11.

V. Discussion. In considering groups several findings stand out as important. First, the organic cases showed a striking tendency to present either unusually long or unusually short reflex times (height held constant). On the basis of the findings and interpretations of *Hoffmann,* and *Travis* and *Dorsey* this implies that the cases with lesions of the central nervous system have

Fig. 10. Portion of the record of the action currents recorded during voluntary movement of Case No. 64 (neurosyphilis, meningo vascular type) showing action currents exceptionally free from *Nebenzachen,* at a frequency of 670 per sec.

disturbances in the usual relationships between higher and lower levels, the most easily demonstrated relationship being a dominance of the former over the latter. In attempting to explain or predict the direction of change in the relationship between higher and lower levels one would have to know the type, locus,

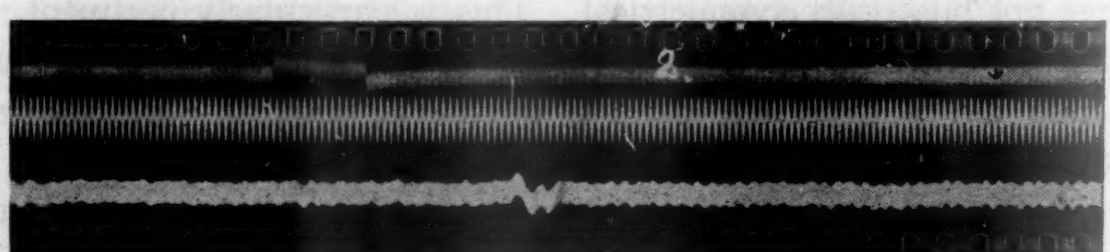

Fig. 11. Patellar tendon reflex record secured from Case No. 67 (Parkinson's syndrome). There were no typical reflex volleys recorded, but instead a late discharge appeared 33.5 σ after the stimulus. In this record the upper line is the signal.

extent, and age of the lesion. For example, one would not expect to find such striking changes in a case with a non-progressive lesion of long standing as in a case with a lesion of very recent origin. For a further study one could more carefully evaluate the anatomical and physiological factors in relation to experimental findings.

A second finding is that the psychoneurotics and schizophrenics did not present any changes in the reflex response latency or in

the voluntary and reflex action current frequency or general patterning to distinguish their records from those of normal individuals. In this connection the relative severity of the disorder at the time the records were secured should be taken into consideration. Without exception all of our cases falling within these two groups were mild. In such mild cases our findings stand against the possibility of any striking changes in the central nervous system.

A third finding is that the paranoid cases gave relatively short reflex times (large H/T values) and a large S.D. in the distribution of these times. In terms of the interpretations of the previously mentioned investigators the greater H/T value implies that these cases possess relatively inactive higher levels. These particular findings must be scrutinized in terms of the small number of cases.

A fourth fairly well established result is that in many organic cases a significant difference exists between the patellar tendon reflex times of the two sides. This implies that the organic disturbances are not bilaterally equal. This finding is in line with clinical observations which indicate that often the disturbances are not bilaterally symmetrical. This is particularly pertinent in the present study in view of the fact that the majority of our cases did not present definite unilateral, clinically determined abnormalities.

A fifth finding is that, in general, voluntary action current frequencies are greater than reflex action current frequencies. This is contrary to the findings reported by *Travis* and *Lindsley* with a small number of normal individuals. At this time we are unable to give an explanation of this apparent difference between normal and abnormal groups.

A study of the records of individual cases reveals interesting additional findings. Here we may list such results as continuous action current activity, consistently late discharges, consistently early discharges, periodic and aperiodic after-discharges, and exceptionally long action current volleys in the reflex discharge proper within the reflex records; and periodic and aperiodic variations in the intensity of action currents, the appearance of action

currents approximating sine wave form, and action currents of exceptionally slow rate in voluntary action current records. Practically all of the characteristics of the reflex records listed above were reported by *Travis* and *Dorsey* in their studies of the effect of alcohol on the reflex time and of reflex time in psychiatric and neurologic cases. All of their cases, however, presented profound alterations of higher level activity, the majority of such alterations being in the direction of a striking depression. On the basis of their studies we may interpret our findings to mean that in psychiatric and neurologic cases in general there is an alteration of the normal relationship between higher and lower levels. This may be in the direction of either hyperactivity of the superjacent levels with a consequent hypoactivity of the subjacent, or a hypoactivity of the superjacent levels with a consequent hyperactivity of the subjacent levels.

VI. Summary and conclusions. In the electromyographic records of the action currents during both reflex and voluntary movement in 66 psychiatric and neurologic cases, results were obtained which may be summarized as follows:

1. A mean H/T value of 8.60 with an S.D. of .903 was found for the entire group of subjects. This mean is slightly lower and the S.D. is much larger than that found for a group of normal individuals.

2. The mean of H/T value for the group of subjects presenting functional disturbances was found to be 8.50 with an S.D. of .387. The mean H/T value for the group of subjects presenting organic disturbances was found to be 8.62 with an S.D. of 1.080. The difference between these groups and also between the latter group and the normal group is primarily in the scatter of the H/T values as indicated by the large S.D. of the latter group.

3. In 11 cases showing organic disturbances in which reflex times were determined on both the right and the left sides, small but significant differences in the reflex times between the two sides were found.

4. For the entire group of 66 subjects, the coefficient of correlation between the height and reflex time was found to be $.46 \pm .062$. The correlation between height and reflex time for

normal individuals was found to be .73±.029 by *Travis* and *Young* and .76±.038 by *Whitehorn* and *Lundholm*.

5. The variation within a single series of records secured from psychiatric or neurologic cases was approximately the same as the variation within a single series of records secured from a normal individual.

6. In the majority of cases from which the frequency of both reflex and voluntary discharges were determined, it was found that the frequency of the action currents in voluntary movement was greater than the frequency of action currents in reflex movement.

7. Significant qualitative differences between the records secured from psychiatric and neurologic cases and those secured from normal individuals were noted in many cases.

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A CLINICO-EXPERIMENTAL APPROACH TO THE REËDUCATION OF THE SPEECH OF STUTTERERS

by

LEO BERNARD FAGAN

I. Introduction. Clinicians in speech pathology have observed a close chronological relationship between an enforced change in handedness and the inception of stuttering. A few isolated and meager reports in medical, psychological, and educational literature indicate in certain cases a therapeutic relief and even cure by reversion to the native hand. *Whipple* (10) reported disturbances in the speech of two cases, one of stuttering accompanied by word blindness and the other of speech retardation which followed compulsory usage of the right hand and which cleared up after reverting to usage of the left hand. *Ballard* (1) cited a case of stuttering relieved by a reversion in motor leads to the original hand. *Nice* (5) reported a case of retarded speech that spontaneously improved when permitted to use the native left hand. *Claiborne* (3) writes that three cases of stuttering cleared up following preferential usage of the left hand. It is noteworthy that these case reports, with the exception of *Nice* (5) indicate no speech reëducative techniques as such, but successful treatment seems to have consisted solely of reversion to the dominant use of the native hand.

The success reported by the clinicians in these isolated attempts coupled with our own observations of the chronological relation of enforced manual changes to the onset of stuttering prompted us to undertake a clinico-experimental study to determine partially the genuineness of the apparent causal-sequential relationship mentioned above, and to determine if success in speech reëducation can be prognosticated by case histories and a battery of selected motor lead tests.

II. Diagnostic measures. The diagnostic measures employed in this study consisted of (1) case histories; (2) physical examination; (3) intelligence tests; (4) tests of motor lead. In addition a majority of the cases were given the *Woodworth-House Mental Hygiene Inventory* and subjected to a careful interview study of their personality characteristics.

III. Case history. A complete life history was found to be of great value and clinically indispensable in diagnosing cases of stuttering. The facts of birth, growth and early development with special emphasis on the appearance and development of handedness and speech are of prime importance in the determination of an accurate picture of the sequence and progressive acquisition of complex coördinations. Of great importance and not infrequently the precipitating factor in stuttering is the rôle of the debilitating diseases especially of the febrile type with deliria, effecting in some cases a residual enfeeblement of the dominant speech and correlational cortical gradients.

In a number of cases there can be no doubt but that an enforced interference with spontaneous neurological expression such as a change of handedness, bears a direct temporal relation to the onset of stuttering. Whether the interference be accidental or unavoidable as in fractures of the upper extremities or motivated by educational and social convention the result is largely the same.

Birth trauma such as serious injuries to the cerebrum especially of the fronto-temporal areas may have a close etiological relation to speech retardation and to the onset of stuttering and other speech disorders. Emotionally traumatic episodes and experiences operating as possible precipitating factors in stuttering need be seriously weighed. They may reduce the narrow margin of normality in the physiologic mechanism of speech providing fertile neurologic soil for functional disorder.

IV. Physical examination. A physical examination, conducted by a medical examiner, was obtained in those cases where the findings of the medical history and any present disease condition warranted it. Determined active disease processes and structural

anomalies of the speech and vocal mechanism were absent in all of our cases.

V. Intelligence tests. We used the *Stanford-Binet,* the *Otis* (higher examination, Form A.), the University of Iowa Qualifying Examinations (1923, 1924, 1925, 1926, 1927) and the *Pintner-Patterson* performance test for estimates of intelligence. Some of our university student patients had previously taken the University of Iowa Qualifying Examination. Other cases were given the *Stanford-Binet* or the *Otis* depending upon the degree of the speech involvement and the chronological age. A case presenting speech blocks of marked duration and intense emotional reactions was given the Otis test, or if very young in chronological age, the *Pintner-Patterson* performance test, in order to avoid the penalties for delayed speech responses that might arise in the *Stanford-Binet* procedure.

VI. Personality examination. Personality was studied by means of the case history, the *Woodworth-House Mental Hygiene Inventory* and personal interviews. The case history furnished information in respect to definite changes in personality and estimates of the personality characteristics. The *Woodworth-House* inventory is a standardized questionnaire for studying emotional maladjustment. The personal interviews consisted of an exploratory study of the personal and social adjustments especially of those in relation to the speech disability.

VII. Tests for motor lead. In a case analysis a positive history of left handedness with partial or complete shift to the right hand (the acquisition of conventionally or educationally required skill with the right hand) is extremely significant. However, a negative history of left handedness may be regarded as of little or no value in view of the social pressure unwittingly brought to bear on the child at an early age by right handed parents and teachers without due regard for the native manual expression. As supplementary indices, tests for native motor lead have been adapted to the needs of this study.

Motor lead, defined in terms of performance, is the functional superiority of the executive structures of one side of the body over the corresponding structures of the other side of the body.

The functional superiority, according to the test norms, consists of the following:

1. primacy of response in simultaneous adductive-abductive movements of the two hands
2. physiologic preference of one eye in ocular fixating and sighting
3. temporal superiority of one hand in tracing a star
4. orientation in simultaneous writing with both hands

A wide number of motor lead tests have been used to determine native handedness but it is felt that all of these are largely measures of training rather than of native physiologic manual lead which has been largely obscured by training. Such tests as winding string on a ball, strength of grip, cutting with scissors and throwing a ball may be mentioned as examples. On the basis of the lack of high reliability of any single measure of handedness in examining an individual case, a battery of four motor lead tests was used as a diagnostic index, especially in those cases presenting a negative history of manual change. Three of these were developed in this clinic.

The test of simultaneous anti-tropic movements of the two hands devised by *Travis* and *Herren* (9) was used to determine the primacy of one hand over the other in initiating simultaneous adductive and abductive movements in relation to the mid-line of the body. In this test *Travis* and *Herren* found that the right handed normal speaker leads more frequently with the left hand while a left handed normal speaker leads more frequently with the right. The right handed stutterer gave performances comparable to the left handed normal.

For determining eyedness the *Parson* method was used (7). *Travis* (8) has found that there is a greater per cent of left eyed individuals among the right handed stutterers than among the right handed normal speakers.

The standard laboratory star-tracing test was employed to determine the superior hand of the stutterer in mirror tracing.[1] It was used by *Travis* (8) in a study of right handed stutterers and right handed normal speakers. He found that the majority of right handed stutterers presented more facility in tracing the

[1] For a history of this test see Carmichael, L., The history of mirror drawing as a laboratory method, *Ped. Sem. & J. Gen. Psychol.*, 34, 1927, 90–91.

star with the left than with the right hand, while just the reverse was true of right handed normal speakers.

The test for simultaneous writing, as elaborated later in this study, determines the graphic orientation lead when both hands write the same thing at the same time. Briefly our findings indicated that the right handed stutterer tended to produce letter reversals with either hand or with both hands while the right handed normal speaker produced relatively few reversals with either hand or both hands.

VIII. Diagnosis for retraining. In making a diagnosis all of the information derived from the case history, personal interviews, mental and emotional tests and motor lead tests was taken into consideration. If a right handed stutterer gave a history of left handedness in childhood, a superiority of the left hand in mirror-tracing, mirrored productions in writing simultaneously with both hands, right leads in adduction-abduction movements and left eyedness, he was shifted back to the left hand in all major manual functions, including writing. This type of stutterer represents the ideal case to be shifted inasmuch as he presents a picture of marked inconsistency between native physiological lead as determined by the history and the motor lead tests and the lead which has been imposed upon him by society. Relatively few stutterers furnish such a perfect case of conflict between native and acquired motor leads. Therefore some decision had to be arrived at in regard to the number of positive indications of conflict in motor lead before an individual's handedness was changed. In general cases were shifted from right to left handedness in all major manual functions under the following conditions:

a. if they gave a history of having been shifted from left to right handedness in childhood.

b. if they gave a history of no change of handedness but gave left hand performances on two of the four motor lead tests. Three individuals who stuttered very severely and who gave but one or no left hand performances were shifted to the left hand.

Those individuals who gave no history of left handedness and either no or only one left handed performance in the motor lead tests were not shifted to the left hand but were subjected to a retraining program involving associating speaking with writing

of the right hand. Three individuals who gave two left leads were not shifted to the left hand because of their ages at, and the unusual conditions attending, the onset and the mildness of the stuttering.

IX. Retraining technique. Although the individuals who were shifted to the left hand were required to carry on practically all manual functions such as throwing, feeding, and combing hair with the left hand, most emphasis was placed upon writing about which was organized the bulk of the retraining exercises. On this latter function we laid great stress because of its involved cortical and neuro-muscular character and because of its close association with articulate speech. Writing is a complicated form of expression which may be thought of as graphic speech. We attempted to establish an intimate association between it and verbal speech by having the stutterer write and speak the same thing initiating the writing movements slightly before initiating the speech movements. This latter procedure was thought important because the lead was then established in a function in which he was not having any appreciable difficulty. The efficacy of linking up speaking with writing is based upon the assumption that the writing will cause a general motor lead to be established which in view of its close and fundamental association with speaking would eventually give to speech an adequate lead of its own. This neuro-educational procedure has for its support certain demonstrable clinical findings. The functional inter-relation of graphic and articulate speech is demonstrated in the clinical manifestations of aphasia with unilateral lesions. With the destruction of cortical material manifested chiefly in disordered articulate speech, there is usually found a concomitant deterioration of the writing function. Furthermore, those right handed stutterers who present a positive history of change from left to right handedness or who present left motor leads or both very frequently show writing abnormalities in the form of letter reversals. In the case of a change from left to right handedness followed by stuttering, the change in lead forced upon the lateral neuromuscular mechanisms seems to constitute the direct cause of the

central conflict or confusion in the enervatory processes of the mid-line levers of the speech mechanism.[2]

We aimed by our training techniques to develop pure sinistrality or pure dextrality or pure unilaterality especially as expressed in motor lead. Daily observations indicated that the stutterer usually improved progressively in his speech fluency, *i.e.*, the physiological symptomatologies (clonic and tonic spasms, etc.) slowly disappeared, growing less and less in both intensity and extensity. Self-confidence accompanied this progressive increase in speaking successes and a steady diminution of speech failures, and acted as a psychotherapeutic aid.

In our clinical reëducative situation the stutterer was in his own sympathetic social milieu, the partners manifesting reciprocal consideration and empathy for each other. The stutterer was removed as much as possible from his old environment where he had felt embarrassments and compulsions to speak with a fluency and ease of normal people. In the presence of his stuttering companions and our own empathetic attitude he was less inclined, on the basis of his reports to us, to feel this compulsion and embarrassment. Competition toward too rapid improvement between individuals was indirectly discouraged because it was felt that competition tended to create tensions, haste and disappointments in the face of slowly yielding affective unconditioning and the necessarily slow establishment of new neurological action-patterns.

X. Cases. Thirty-three right handed stutterers, ranging in age from four and a half to twenty-eight yrs. served as subjects. Five cases were females.

XI. Results. The results of the various examinations and of the retraining program are summarized in Tables I to V inclusive. Improvement in speech was determined by reports from parents and associates of the stutterer and by periodic observations of his speech by members of the speech clinic staff. In addition, for a number of the stutterers, improvement was determined by having them keep a record of the number of times per day they had difficulty.

[2] For a fuller discussion of these concepts see Travis, L. E., Speech pathology. N. Y.: D. Appleton & Co., 1931, 331.

TABLE I. *Cases definitely left handed in early childhood and required by us to return to the left hand*

Case	Age	Sex	I.Q.	Age (in yrs.) of enforced change in handedness	Age (in yrs.) of onset of stuttering	Motor lead performances	Personality test results	Progress to date
I	12	M	131	5	5	3R 1L	average adjustment	improved at 3 mos.
II	4	M	135	2	2½	1R 2L	average adjustment	normal speech at 28 mos.
III	20	M	119	6	9	1R 3L	maladjusted	normal speech at 12 mos.
IV	12	M	83	6	7	3R 1L	average adjustment	marked improvement at 8 mos.
V	8	F	106	3.5	4	2R 2L	maladjusted	normal speech at 6 mos.
VI	19	M	113	4	4	2R 2L	maladjusted	normal speech at 10 mos.
VII	28	M	127	6	7	1R 3L	well adjusted	improved at 3 mos.

TABLE II. *Cases ambi-dextrous in early childhood and required by us to use the left hand*

Case	Age	Sex	I.Q.	Age (in yrs.) of enforced right handed preference	Age (in yrs.) of onset of stuttering	Motor lead performances	Personality test results	Progress to date
VIII	13	M	135	5	2.5	2R 2L	maladjusted	marked improvement at 6 mos.
IX	21	M	123	2	2	1R 3L	well adjusted	dropped training
X	9	M	122	Injury to right fronto-temporal head region, age 4	4	2R 2L	average adjustment	improved at 28 mos.
XI	20	M	12 percentile	1	2	2R 2L	maladjusted	dropped training
XII	29	M	91	1	3	2R 2L	maladjusted	improved at 5 mos.
XIII	22	M	122	1	5	2R 2L	maladjusted	normal speech at 20 mos.

TABLE III. *Cases with negative histories of left handedness but whom we changed to the left hand*

Case	Age	Sex	I.Q.	Age (in years) of onset of stuttering	Motor lead performances	Personality test results	Progress to date
XIV	12	M	115	4	1R 3L	Average adjustment	Marked improvement at 9 mos.
XV	21	M	113	13	2R 1L	Maladjusted	Normal speech at 18 mos.
XVI	16	F	110	7	2R 2L	Average adjustment	Normal speech at 32 mos.
XVII	16	M	117	10	2R 2L	Maladjusted	Normal speech at 10 mos.
XVIII	22	M	123	5	2R 2L	Maladjusted	Marked improvement at 53 mos.
XIX	23	M	113	3	1R 3L	Maladjusted	Marked improvement at 37 mos.
XX	13	F	93	4	0R 4L	Average adjustment	Normal speech at 9 mos.
XXI	20	F	118	7	1R 3L	Maladjusted	Marked improvement at 8 mos.
XXII	17	F	105	10	0R 4L	Maladjusted	Normal speech at 7 mos.
XXIII	20	M	105	2.5	1R 3L	Maladjusted	Normal speech at 23 mos.

TABLE IV. *Cases with negative history of any left handedness in childhood and whom we did not change to the left hand*

Case	Age	Sex	I.Q.	Age (in years) of onset of stuttering	Motor lead performances	Personality test results	Progress to date
XXIV	19	M	113	13	3R 1L	Average adjustment	Normal speech at 14 mos.
XXV	19	M	104	5	2R 2L	Maladjusted	Dropped training
XXVI	22	M	109	4	3R 1L	Maladjusted	Dropped training
XXVII	23	M	56 percentile	17	1R 3L	Well adjusted	Normal speech at 7 mos.
XXVIII	22	M	76 percentile	8	3R 1L	Maladjusted	Improved at 3 mos.
XXIX	19	M	98	3	3R 1L	Average adjustment	Normal speech at 4 mos.
XXX	29	M	115	18	4R 0L	Maladjusted	Improved at 6 wks.
XXXI	22	M	92 percentile	3	3R 1L	Maladjusted	Dropped training
XXXII	18	M	7 percentile	18	3R 1L	Average adjustment	Dropped training
XXXIII	22	M	105	5	3R 1L	Maladjusted	Dropped training

TABLE V. *Group summaries of results of re-training program*

Groups	Attained normal speech	Markedly improved	Improved	Dropped training
I. Left handed in childhood whom we shifted back to the left hand. N=7	4 or 57%	2 or 28%	1 or 14%	0 or 0%
II. Ambidextrous in childhood whom we shifted to the left hand. N=6	1 or 16%	1 or 16%	2 or 33%	2 or 33%
III. No history of left handedness whom we changed to the left hand on the basis of motor lead test results N=10	5 or 50%	5 or 50%	0 or 0%	0 or 0%
IV. No history of left handedness whose handedness was not changed by us. N=10	3 or 30%	0 or 0%	2 or 20%	5 or 50%
Total	13 or 39%	8 or 24%	5 or 15%	7 or 21%

An examination of the tables revealed the following facts: (1) Twenty-three or 66 per cent of the cases were changed to the left hand. Ten or 43 per cent of this number of cases attained normal speech. (2) Ten or 34 per cent of the cases were not changed to the left hand. Three or 30 per cent of this number of cases attained normal speech. (3) The time required for the attainment of normal speech ranged from four to 32 months with an average of 14 months for all cases; 16 months was the average for cases shifted to the left hand and eight months for those not shifted. (4) Thirteen or 39 per cent of the stutterers are still in training; of the 11 shifted to the left hand, eight are markedly and three noticeably improved. Two of the 13 cases not shifted to the left hand are markedly improved. (5) Seven or 21 per cent of the stutterers dropped training or have not reported their progress after the initial reëducational measures. (6) Twenty-six or 79 per cent of the total number of cases were either improved or cured. (7) In regard to etiological factors brain injury appeared to be operative in one case, a shift from left to right handedness in 13 cases, febrile diseases with deliria in two cases, and transient nervous disorders such as benign chorea in three cases. (8) Mild emotional maladjust-

ments were observed in the majority of the stutterers. It was felt that their relation to the onset of stuttering could not establish them as of definite etiological importance.

XII. Summary. From the speech achievements of those stutterers shifted to the left hand and of those who were not shifted, success of reëducation programs was prognosticated in 39 per cent of the cases on the basis of case history data and motor lead performances. If the criterion of the value of our reëducational method is extended to include " marked improvement " then success was prognosticated in 63 per cent of the total number of stutterers. The success of our reëducational technique in changing the majority of right handed stutterers to the left hand may partially justify the relationship between handedness and speech as observed when stuttering follows upon changes in handedness.

XIII. A comparative study of the simultaneous writing performances of stutterers and normal speakers. Mirror-writing as a clinical test and laboratory experiment has been widely used and reported during the last half century. It has been employed in studying the writing orientations of pathological and normal subjects with special reference to the reversal of letters written by the left hand.

Fuller (4) made an extensive study of mirror-writing by pathological and normal cases and by normal individuals in hypnotic and toxic states. With the exception of the deaf and dumb his pathological groups did not include speech defectives. Only two of his 77 subjects making up the three groups wrote mirror-wise with the left hand. From a university group of normals (31 subjects) in the waking state only six individuals showed a rather strong tendency to reverse the left hand figures while writing simultaneously and rapidly with both hands and the eyes closed. It is significant that all of them reversed a few lines, mostly the first strokes of the figures. *Blom* (2) in summarizing the literature on mirror-writing states that: ". . . mirror-writing is as normal for left handed people as the conventional writing is for right handed people." No work bearing directly on mirror-writing by stutterers has been found.

From the studies of *Orton* and *Travis* (6), *Travis* (8), and

Travis and *Herren* (9) we have reasons to hold that many right handed stutterers have a native left physiological lead and if, according to *Blom,* mirror-writing or the right-to-left orientation is normal in the spontaneous sinistral writing of left handed individuals then the right-to-left orientation would be more apt to be expressed in the sinistral writing of right handed stutterers and thereby offer a further clue to the native physiological lead. This phase of the study was undertaken to throw some light upon the problem.

There are several methods of determining the ability of an individual to write mirror-wise. One is to have him close the eyes and write with both hands simultaneously. Another is to show him a sample of mirror-writing and after having explained to him its nature have him write in a similar fashion, first with the left and then with the right hand. A third method is to have him write with both hands but with the left intentionally in mirror script. We selected the first method of testing this ability since it presents a task in which the two hands are on a relatively equal basis.

Simultaneous writing admits of four possible writing orientational combinations as follows: both hands move to the right; both hands move to the left; the left hand moves to the left and the right hand moves to the right; and the left hand moves to the right and the right hand moves to the left.

In the administration of the test the subject stood facing a blackboard, each hand holding a piece of chalk in contact with the writing surface. He was instructed to keep his eyes closed throughout the performance and to write quickly and simultaneously with both hands whatever he was told to inscribe. In general each subject was asked to write every letter of the alphabet as it was pronounced to him both as a capital and a small letter and the numerals, 2, 3, 4, 5, 6, 8, and 9. In addition certain short words such as "cat", "dog", and "boy" were given.

The 69 non-stutterers who served as normals in this study were all right handed adults ranging in age from 19 to 50 yrs. The 50 stutterers ranged in age from four to 45 yrs. and all were "right handed" at the time this experiment was carried on.

XIV. The following results were obtained:

1. Sixteen or 23 per cent of the normal speakers showed reversals.

2. Fourteen of these 16 individuals reversed but one character.

3. Two of these 16 individuals reversed but two characters.

4. Seven or ten per cent of the normal speakers reversed with the left hand only.

5. Nine or 13 per cent of the normal speakers reversed with the right hand only.

6. Not a single normal speaker reversed with both hands.

7. Twenty-nine or 48 per cent of the stutterers presented reversals.

8. Nine of these 29 stutterers reversed with the right hand only.

9. One of the 29 cases reversed with the left hand only.

10. Three of the 29 cases always reversed with both hands simultaneously.

11. Sixteen of the 29 cases reversed with first one hand and then the other or with both hands at the same time.

12. Twelve or 24 per cent of the right eyed stutterers gave reversals while 14 or 28 per cent of the left eyed stutterers gave reversals.

From these findings it is seen that normal right handed speakers show only slight tendency to write in mirror-script with either hand or with both hands, whereas right handed stutterers reverse frequently with either or both hands. It is significant that stutterers write in the mirrored form more frequently with the right than with the left hand.

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GRAPHIC STUTTERING

by

Leo Bernard Fagan

The clinical examination of a stutterer, a white American unmarried female, 29 years of age, of superior intelligence, and in normal health and physical condition, revealed an unusual form of writing disability which may be described as graphic stuttering.

She has stuttered severely since early childhood but had a period of remission, in 1925–27, from practically all her speech difficulties. The symptoms returned after debilitation from a febrile disorder diagnosed as "influenza". After convalescence and recovery her speech again improved somewhat until Jan. 1930. At this time her fauceal tonsils were removed and left antrum punctured under local narcosis induced by means of novocaine; in a short time after the drug-effects wore off she began again to stutter severely.

The writing disability dates from the first grade when writing with the right hand was first acquired. Her teachers have always rated her writing as very poor, barely passing in quality for it was small, cramped and wavy in line, and the letters were occasionally made upside down or backward. She related that there was marked improvement of her writing during the periods of remission but it again became of poor quality when the stuttering returned.

Samples of the right handed writing were selected at random from one of her lecture note-books (Fig. 1). Underlinings indicated scriptural disturbances as they occurred in note taking. In sentence 7 spasms occurred in the upper loop of the "g" and in forming the "l" in "logical". In sentence 8 the "m" in "method" was inverted then corrected. The word in the last line of paragraph 9 was transposed; she intended to write

" force self into situation " but instead she wrote " self into rforc situation ". In sentence 1 of paragraph 10 the two " t's " in " attend " were first inverted and then corrected; in sentence

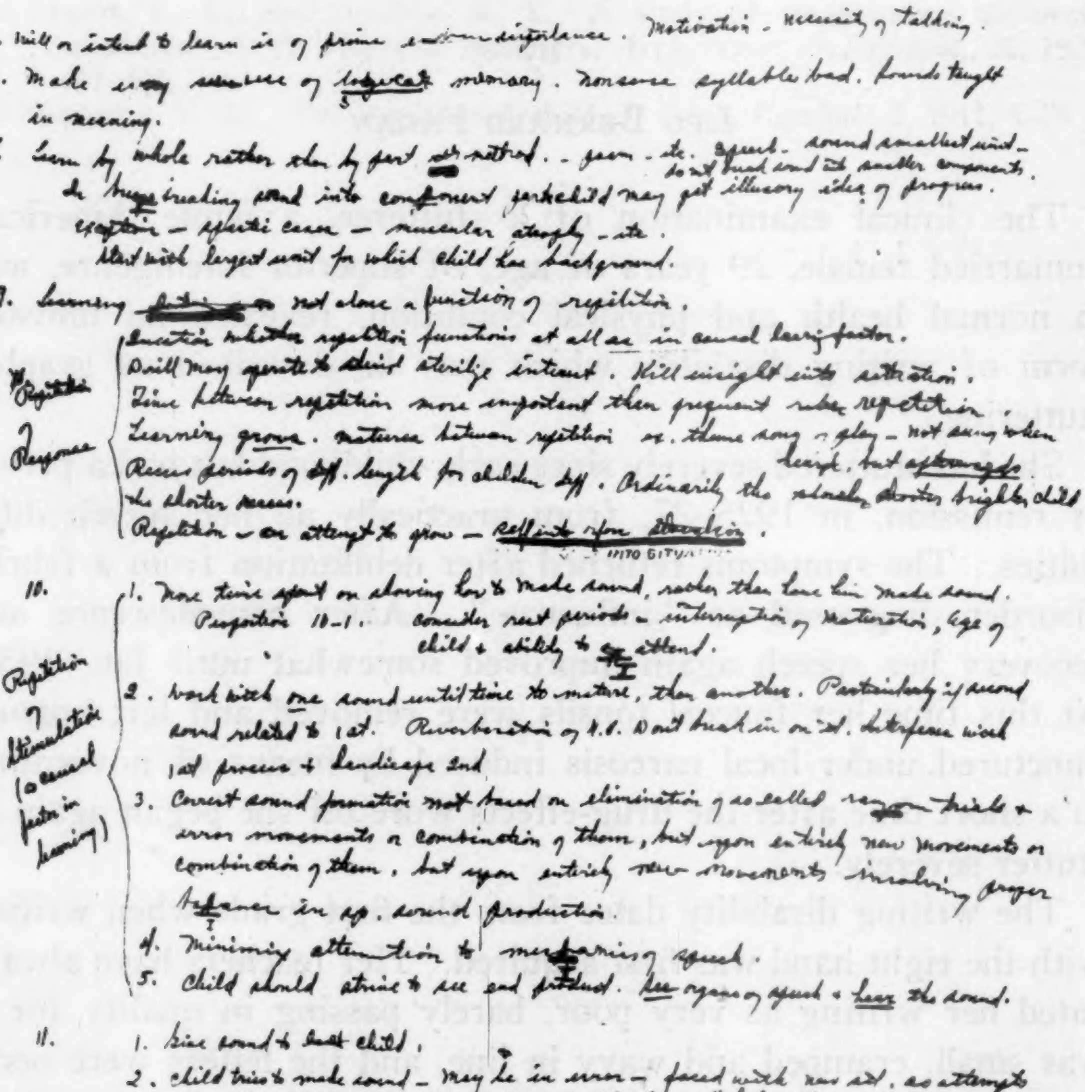


FIG. 1. Sample of right-hand writing selected from a note book.

3 of the same paragraph the " d " in " random " and the " l " in " balance " were inverted. In sentence 4 of paragraph 10 the " h " in " mechanics " was inverted. In line 3, paragraph 11, spasms and inversions are found.

The breathing movements were studied in relation to the graphic speech in having her speak and write at the same time about anything with which she was familiar. The laryngeal,

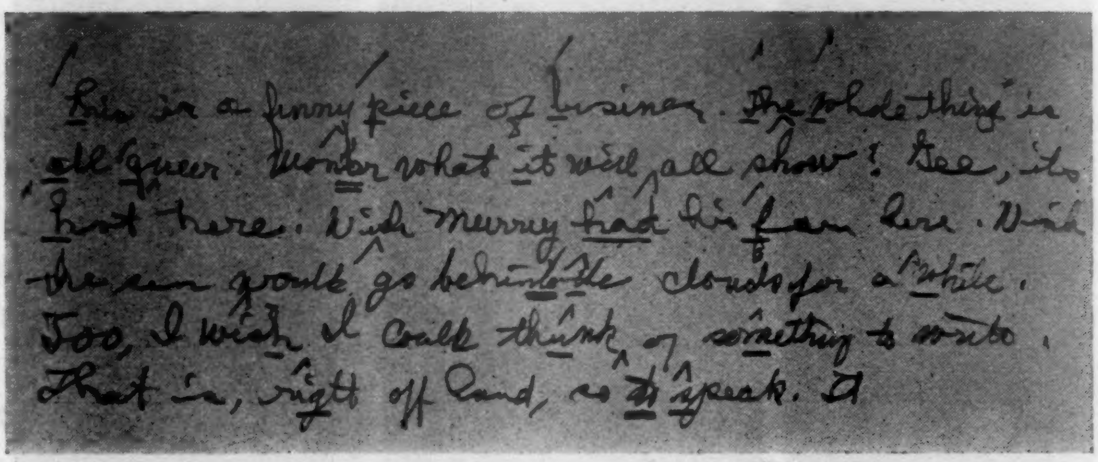


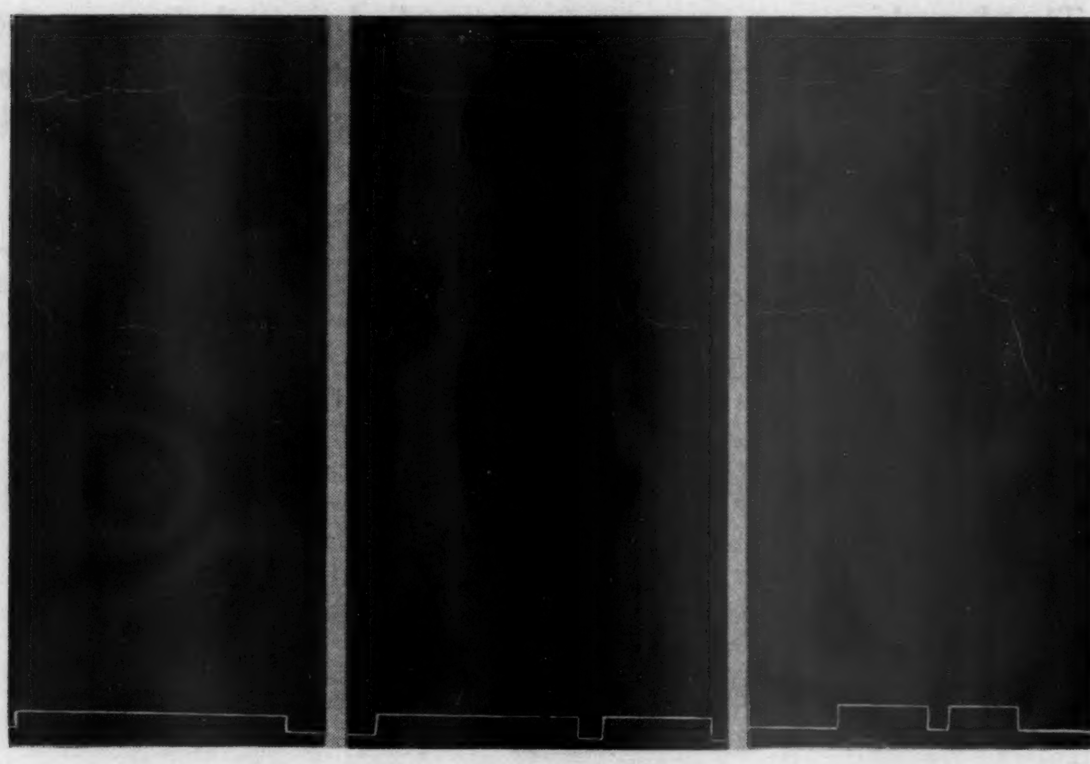
FIG. 2. Spontaneous writing while speaking and writing the same thing.

FIG. 3 FIG. 4

FIG. 3. The breathing record of a right handed normal individual while speaking and writing the same thing. Reading from top to bottom for this and all subsequent records, the first curve registers vertical movements of the larynx; the second, movements of the thorax; the third, movements of the abdomen and the fourth, time in secs.

FIG. 4. A breathing record of our stutterer during silence.

thoracic and abdominal movements were registered on a kymograph. The patient sat in a right-arm chair with her back to the apparatus. *E* was situated immediately in front and observed



A B C

Fig. 5

D E F

Fig. 5 (cont.)

Fig. 5. A, B, C, D, E and F. Breathing records of our stutterer while speaking and writing the same thing. Elevation of the signal line indicates graphic disturbance.

only the writing movements; the breathing movements were recorded by the kymograph.

In writing the incipient movements momentary to the initiation of writing a word were tremorous and spastic showing a correspondence to the general type of verbal stuttering. The underlined letters and words indicate when graphic disturbances, spasms and reversals occurred (Fig. 2). Twelve of the 21 disturbances occurred in the act of word initiation.

The breathing movements of a normal individual while speaking and writing the same thing were recorded under the same laboratory conditions as those obtaining for our stutterer. The breathing movements of normal speech show a fairly constant relation between movements of the thorax and abdomen; the relative independence of the laryngeal movements is a finding common to many observers (Fig. 3).

The breathing movements from the thorax and those of the abdomen of our stutterer during silence are synchronous (Fig. 4). Her breathing records during speech and writing show: (1) a marked concomitance of dysintegrated breathing movements and graphic disturbances; (2) antagonisms, anachronisms, tonic and clonic spasms occurring simultaneously and alternately; (3) a tendency for gross tremor spasms occurring more frequently in the abdominal and laryngeal than in the thoracic movements; and (4) a misproportion between gross extent of the thoracic and of the abdominal movements during speech and writing as compared to those during silence (Fig. 5 A-F).

A LABORATORY STUDY OF DIAGNOSTIC INDICES OF BILATERAL NEURO-MUSCULAR ORGANIZATION IN STUTTERERS AND NORMAL SPEAKERS

by

HERBERT H. JASPER

I. Introduction. The importance of the functional organization of bilaterally paired neuro-muscular systems has become paramount in the study of various disorders of speech. The evidence from studies of unilateral hand preference in habitual manual acts (78, 50, 35) indicates that a higher percentage of stutterers have a lack of definite unilateral preference than do normal speakers. The clinical and laboratory findings of *Claiborne* (21), *Sachs* (85), *Orton* (80), *Travis* (99) and others have given evidence to support the view that stuttering is causally related to a lack of unilaterality in neural organization. With particular reference to stuttering *Travis* expresses the "dominance" theory of bilateral neural organization as follows: (99)

> "The neurological basis of stuttering which is a lack of a sufficiently dominant gradient of excitation in the central nervous system is largely a pathophysiological variant. We may think of its existence in terms of a margin of dominance which exists in range from zero amount to a large and safe amount in different individuals . . . the act of stuttering is a neuro-muscular derangement secondary to general reduction in cortical lead control. The latter is conceived to be due to transient and mutually inhibitive activities of the right and the left cerebral hemispheres. In the stutterer instead of nervous energy being mobilized by one center of greatest potential it is mobilized by two centers of comparable potential. Because both of these centers when operating singly function in reaction patterns of opposite motor orientation and configuration there is produced in the peripheral speech organs an undesirable competition in the resulting muscular movements. The symptoms of stuttering are then mainly the peripheral signs of the rivalry between the two sides of the brain."

The two major aspects of this theory are (1) that a certain margin of dominance of the higher centers over the lower is

necessary for the integrated activity of peripheral structures and that when this margin of dominance is in any way reduced, bilateral incoördination results; and (2) that the cause of the reduction in the effective control of the higher centers, in most cases of stuttering, is an equalization of the balance of power between the two halves of the nervous system; neither the right nor the left hemisphere is able to get control. The control of one hemisphere over the other is a necessary condition for the integration of impulses going to bilaterally innervated peripheral systems.

From this point of view we would assume that the basic difference between the stutterer and the normal speaking individual lies in the relatively greater degree of "dominance" in the neural organization of the latter. This "dominance" is conceived primarily as a "dominance" of higher over lower centers resulting from a unilateral dominance in the structurally bilateral system.

The relation between handedness, *i.e.*, manual preference in the majority of habitual manual acts, and basic laterality of neural organization is not as simple as it might seem at first thought. It is a relatively simple matter to determine an individual's handedness by merely getting reliable information concerning which hand is preferred in the majority of a sufficiently large sampling of unimanual acts, but handedness *per se* is not the *sine qua non* of the basic orientational laterality within the organism as a whole (assuming that there is such). Right handedness may be a peripheral superstructure overlying a foundation of sinistral tendencies in the more central components of the organism. Since this is precisely the condition which has been set forth as participating in the etiology of pathological conditions having for their major symptoms the dysintegration of bilateral functioning, it is necessary and important to obtain indications of laterality other than handedness.

There has been a great number of researches conducted on dextrality and sinistrality (34) with varied methods of approach. Some of these researches have contributed chiefly to our understanding of the basic nature of unilaterality and others have resulted also in clinical methods for use as indices of basic lateral-

ity of " native handedness ". *Travis* (99) has selected what he has considered to be the best of these indices and added to them from his own researches to form a battery of clinical tests for use in Speech Clinics. These tests, together with case histories, form the basis for the diagnosis of stutterers for remedial treatment by the method of developing a greater margin of unilateral dominance according to the indicated laterality of " native " dominance.

Clinical tests for use in individual diagnosis must have a high degree of reliability and validity to be practical as guides to therapeutic procedure. *Travis* and his students have presented considerable evidence for the diagnostic value of their battery of tests for use with stutterers. Treatment on the basis of this diagnosis has shown encouraging results. Since, however, all of the tests in this battery are still in the experimental stage, one of the objects of the present study is to provide additional information on the " test of the tests ".

The second and perhaps the major aim of this study was to attack the problem of the nature of the bilateral neural organization of stutterers and normal speakers by means of some new methods of approach. These methods had been limited entirely to those adapted from the neurological and psychological laboratories. This entire study dealt with bilateral neural organization only as it was revealed by diagnostic tests and was consequently related to the results of therapeutic methods only insofar as this type of diagnosis participated in these methods. The diagnostic methods of approach contribute chiefly to an understanding of the immediate condition of bilateral neural organization in stutterers and normal speakers.

II. Selection of subjects. An inventory of habitual hand preferences in 76 unimanual acts formed the basis of selection for the normal speaking subjects. This inventory was arranged in questionnaire form and administered to 332 students in the elementary psychology classes of the University of Iowa. It was not " sent out " as an ordinary questionnaire but was made a part of the regular requirements for the laboratory work in the course. Only 350 questionnaires were issued so that the 332 returned is a

fair sampling of the entire group. The questionnaire was issued in a laboratory period with full instructions, both written and oral, as to how to fill it out and also with emphatic instructions *not* to answer a single item until each person had observed his own behavior for a week and had tried out every item he answered. The questionnaire in the form used appears in the appendix. Eleven bimanual acts were included with the unimanual acts more for the purpose of testing their relation to unimanual preferences than for getting reliable indications of handedness.

The items appearing in this handedness inventory were selected in an arbitrary manner and the types of activity represented were classified as right or left handed solely on the basis of which hand showed the most habitual preference. Only the unimanual acts were considered in the scoring. The number of ambidextrous responses was not considered in the scoring of handedness. The score was obtained by subtracting the percentage of all the items answered " left " from the percentage of all the items answered " right ". Hence a positive score indicates a majority of right hand preferences, a zero score indicates the same number of right as left preferences or all ambidextrous preferences, and a negative score indicates a majority of left hand preferences. No attempt was made to weight the individual items since no criterion was available for weighting at the time of the scoring.

Fig. 1 gives the columnar frequency distribution for the 332 cases in the psychology class. This gives a graphic representation of what might be considered the distribution of hand preferences in a fairly random sampling of college students. It will be noted that about 6 per cent of the group fell below zero which is about the per cent of left handedness usually found in a random sampling of cases. It would be necessary to make a more careful test of each item in the inventory together with a weighting of scores for this distribution to be considered valid with respect to the *degree* of unimanual preference. The distribution was used in this study only to provide a basis for the selection of subjects for further study.

The upper 12 per cent of the entire distribution formed our group of right handed normals (RN). The scores for this group

ranged from 88 to 99 with an average of 91. The lowest 6 per cent of this distribution plus eight left handed students outside of this group formed our group of left handed normals (LN). Their scores on the entire inventory ranged from −88 to −5 with an average of −42. The ambidextrous group (AN) was selected from those cases which fell on that portion of the distribution which drops rather rapidly toward the zero point. Their scores ranged from 7 to 70 with an average of 50.

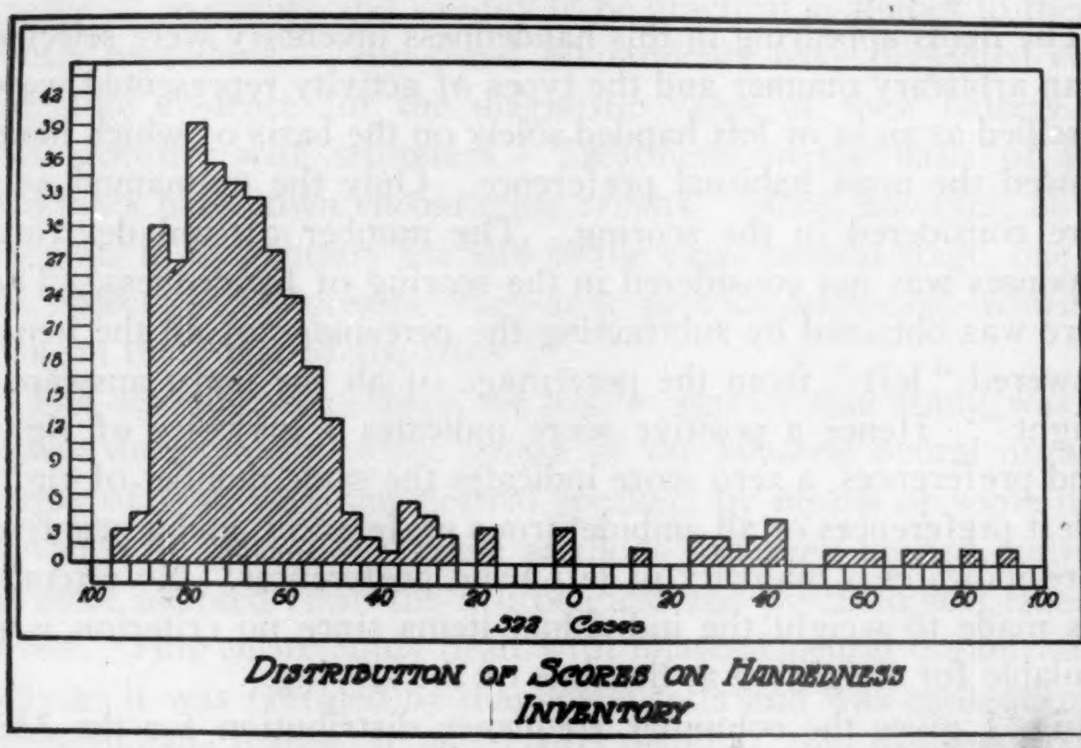


FIG. 1. Distribution of scores on handedness inventory.

No conscious selection operated in the choice of our group of stutterers (S). They were all registered for treatment at the University of Iowa Speech Clinic. With one exception, a very mild stutterer used in only one of the tests, all of the stutterers had a reported history of right handedness. One-half of the number of the group were in various stages of being shifted from the right to the left hand when the measures were taken. Mild, moderate, and severe stutterers were about equally represented in the group.

Table I gives the number, age, and sex of the four groups used in this study. All of the cases represented in this table were used

for some of the measures while a certain percentage of them was used for others.

TABLE I. *Number, age and sex of the four groups of selected subjects*

	Age Range	Av. Age	Men	Women	Total
RN	18–25	20	15	20	35
LN	12–32	21	16	15	31
AN	17–38	21	15	24	39
S	14–30	19	31	9	40
		Av. 20	Total 77	68	145

The percentage of answers R, L, and X on the basis of the total number of answers to all items is given for each group separately in Table II.

TABLE II. *Percentage of R, L, and X responses to handedness inventory*

	RN			LN			AN			S		
	R	L	X	R	L	X	R	L	X	R	L	X
Bimanual	.64	.31	.05	.27	.70	.03	.51	.35	.13	.52	.42	.05
Unimanual	.92	.04	.04	.24	.65	.11	.66	.14	.20	.66	.18	.16

Table II indicated that, within the limits of the validity of our data, we had a very definitely right handed group for the RN subjects, a fairly definite left handed group for the LN subjects and an AN group which matched the S group remarkably well as far as number of right and left hand preferences was concerned. These results alone served to classify the S group with the AN group, a finding which is not without significance in the evaluation of diagnostic tests as well as of some significance pertaining to the general problem of the degree of unilaterality in stutterers. The proper weighting of items in a handedness inventory covering a large sampling of unimanual acts would probably have produced a valuable diagnostic test for clinical use. The bimanual acts seemed to be fairly diagnostic for the left handed group but of little value for the other groups.

III. Clinical tests for "native handedness". The term "native handedness" is used in this connection because the authors of some of the tests herein described have used this term to express the basic laterality of neural organization which may be contra-indicated by the laterality of the majority of present manual preferences. A discussion of the evidence for the hereditary nature of sinistrality and dextrality would lead us too far

afield. The terms " native handedness " or " native physiologic lead " will be used in this study only to express the present orientational laterality within more central aspects of the neuro-muscular system with no assumptions regarding its hereditary or acquired nature. Of course the presence of any such basic orientational laterality is also more or less of an assumption, which will be critically considered at a later point. Because of the frequent use of these two concepts of unilaterality, the term *central laterality* will be used to indicate what has been termed " native handedness " and the term *peripheral laterality* will be used to indicate handedness as judged from inventories of present hand preferences. The term " native handedness " is misleading since there can be little question regarding an individual's handedness as such. It is the sinistrality or dextrality of the more general or central neuro-muscular organization which is often in question.

A great number and variety of tests have been used to investigate neuro-muscular laterality of function. Tests of strength of grip, steadiness of hand, speed of movement, and facility in various sorts of motor coördination (82, 34) have given small differences between the averages of right and left handed groups of subjects, but none of them has been consistently large enough to make these tests useful in individual clinical diagnosis.

The tests used in the first part of this study were chosen chiefly because they formed the battery of tests used by *Travis* and *Bryngelson* in the clinical diagnosis of stutterers and because they were carefully selected for this battery as being the best tests available, although no claim is made for their infallibility. • In fact it was because of the recognized fallibility of a single test that the battery of tests was used to obtain some laboratory index of central laterality. Since a considerable portion of the unilateral aspect of the " dominance " theory of stuttering was based upon the results of these tests, added importance is attached to their critical examination. The tests in this battery were as follows:

Test A: Unilateral sighting.
Test B: Simultaneous writing.
Test C: Motor leads in abduction-adduction movements of the hands.
Test D: Mirror drawing.

Tests of monocular and binocular visual acuity and tests of binocular muscle balance have been added to this list of clinical tests as used in this study.

In evaluating the comparisons to be made between the different groups used throughout this study, it must be kept in mind that each group was composed of extreme cases selected on the basis of handedness as expressed in habitual manual acts. Even the ambidextrous group did not represent the central tendency of a random sampling since the peak of the entire distribution fell much nearer the right handed end of the scale than did the central tendency of the ambidextrous group. Handedness could not be considered a certain criterion for judging general asymmetry in neuro-muscular organization as had been previously stated. but it was assumed that individuals who presented extreme tendencies to unilaterality or ambilaterality in hand preference would have manifested these tendencies in indices of reactions involving other types of asymmetry of function than did handedness. The principle involved in the comparisons was therefore the correspondence between the results of a specific test and the broad criterion of handedness as expressed in habitual manual acts. These comparisons must be considered in every case in the light of the validity of the broad criterion as determining general asymmetry of function.

Test A: Unilateral sighting

The principle of this test is the observation of eye preference of a subject looking through any device which permits only monocular vision without the subject being aware of the fact that he is sighting only with one eye. *Parson's* manoptoscope (82), originally used for this purpose, was the device used in this study for the production of the above type of monocular vision. It is simply a metal cone; the large end is shaped to fit well around both eyes and the small end tapers down to 1 in. in diameter about 10 in. from the eyes. A piece of paper with a 1 in. hole in it held at arm's length will do just as well. The subjects, standing about 8 ft. from *E,* were instructed to raise the cone, look at the bridge of *E's* nose and then take the cone from the

eyes. Fifteen trials were given, five with the right hand holding the cone, five with the left hand holding the cone and five with both hands holding the cone. If the subject showed a preference for either eye 12 out of the total of 15 trials, that eye was recorded as dominant. Subjects were termed amphiocular if they showed less than 80 per cent preference for either eye. *Parson* (**82**), the author of this test, claims that the reason for the effectiveness of this test is that " eyedness is *cause* and handedness is *effect* ". He states further that (*op. cit.*, p. 81), " We can tamper with and superficially change the effect, but without deliberately disabling the sighting eye, we can not change the cause ". Making use of the hypothesis that without the dominance of one eye in perception there would be a confusion between the correct orientation of objects in the field of vision and mirrored perception together with the fact that monocular vision alone will eliminate homonymous and heteronymous doublings, *Parson* maintains that this imperative laterality in vision produces a linking of the hand preference with the eye preference. Regardless of the validity of the theoretical basis of this test it has proved to give sufficient indications of central neural laterality.

Parson states that there are but three possible results with this test: (1) a complete agreement between the manuscopic indication and the ascertained facts, in other words a correct and unqualified diagnosis; (2) a manuscopic indication of right eyedness when the subject is left handed, in which case it will be found that the subject has suffered an injury to the right arm or hand or loss of acuity in the left eye; (3) manuscopic indication of left eyedness whereas the subject is right handed, in which case it will be found that the subject has changed from left to right handedness as a result of injury or enforced training or else he has developed trouble in the right eye.

Parson, together with others, found that 608 out of 877 subjects used the right visual line for sighting. With four exceptions (explained on the basis of sensory defect) all these right eyed persons were right handed. Eighty-nine per cent of the 36 confessed sinistrals were left eyed. Seventy-three per cent of the 841 confessed dextrals were right eyed. The 27 per cent

left eyed dextrals together with the 4 per cent confessed sinistrals places the figure for basic sinistrality at 31 per cent if *Parson's* claim of the infallibility of the sighting test is accepted.

Travis (**98**) found that 73 per cent of the 55 right handed normal speaking subjects were right eyed while only 50 per cent of 48 stutterers were right eyed. *Miles* (**76**) found that about half of the clearly left handed subjects were left eyed while over 70 per cent of the right handed were right eyed. *Travis* and *Bryngelson* determined the eyedness of 301 right handed stutterers ranging in age from 5 to 25 years and found 60 per cent of them were either left eyed or amphiocular (**99**).

Metfessel, in an unpublished study, reports 52 per cent right eyedness in a group of 70 stutterers, 49 per cent right eyedness in a group of 53 left handed normal speakers and 71 per cent right eyedness in a group of 64 right handed normal speakers. His subjects were all younger than the subjects used in this study.

TABLE III. *Per cent of right, left, and amphiocular eye-preference in stutterers and in normal speakers*

Group	Right	Left	Amphi.	N
RN	.74	.23	.03	79
LN	.45	.42	.13	31
AN	.56	.26	.18	39
S	.54	.21	.25	28

The results of the eyedness test on our four groups of subjects, presented in Table III, considered together with the results of the other researches mentioned, serve to decrease the validity of the original claims of *Parson* in regard to the infallibility of eyedness as an indication of central laterality. In fact from these results we would expect three out of every ten right handed normals to be left eyed and we would expect only five out of every ten left handed normals to be left eyed, being purely a chance situation with the left handed and only 20 per cent better than chance with the right handed.

The consistent tendency in evidence from all these researches on eyedness in stutterers and normal speakers served to classify the stutterers as a group with the ambidextrous and left handed normal speakers. This contributed to our understanding of the general nature of the bilateral neural organization in stutterers

as compared with normal speakers, but the small difference between the percentage of right and left handed normal speakers testing distinctly unilateral definitely limited the value of this test in individual diagnosis.

Test B: Simultaneous writing

This test makes use of the mirrored homologous nature of the relation between the right and left halves of the nervous system and of the entire body. The movement of the right hand in a clockwise direction is analogous to a movement of the left hand in an anti-clockwise direction as far as the movement is conditioned by their respective unilateral structures. Hence if the two halves of the body worked independently according to their structural organization, normal writing with the right hand would be associated with mirrored writing with the left hand or normal writing with the left hand would be associated with mirrored writing with the right hand. If both hands write simultaneously in the normal orientation, it is necessary that one-half of the organism dominate in the determination of the direction of movement. In an excellent summary of a large number of investigations of mirror writing *Blom* (8) concludes that mirror writing is the normal sinistral expression.

This test was administered as described by *Travis* (99) in his account of its standardization with right handed normal speakers and stutterers. The subjects were asked to take a piece of chalk in each hand and step to the blackboard with their eyes closed. They were instructed to write as *quickly as possible* with both hands at the same time. Ten letters and ten digits were given as fast as the subject could write them. Records were kept of the number of reversals with the right and the left hand.

There are four possible combinations of writing in this test: (1) right orientation with both hands (RR), (2) mirrored orientation with both hands (MM), (3) right orientation with the right hand and mirrored orientation with the left (MR), and (4) right orientation with the left hand and mirrored orientation with the right hand (RM). A subject may have presented all four of these possibilities during the course of a test. The results

of this test on our four groups together with the original results of *Travis* on his group of stutterers and normal speakers are presented in Table IV.

TABLE IV. *Results of the simultaneous writing test*

	RN		LN		AN		S	
	N	Per cent	N	Per cent	N	Per cent	N	Per cent
RR	26	74	22	76	25	64	14	54
MM	0	0	0	0	0	0	0	0
RM	0	0	0	0	1	3	0	0
MR	0	0	1	3	0	0	0	0
RR MM	1	3	2	7	1	3	1	4
RR MR	8	23	2	7	8	20	5	19
RR RM	0	0	2	7	2	5	1	4
MR MM	0	0	0	0	0	0	1	4
RM MM								
RM MR								
RR RM MR					1	3	2	7
RR MR MM					1	3		
RR MR RM							1	4
RR RM MR MM							1	4
Travis RR							86	30
Mixed							197	70

A larger percentage (1.9 S.D.)[1] of the RN and LN groups had the RR orientation in simultaneous writing than does the AN group, indicating a lack of unilateral dominance on the part of the latter. A still larger percentage (2.1 S.D.) of the RN and LN groups had the RR orientation than did the S group. The difference between the S and AN groups could not be considered of much significance with the small number of cases in these groups.

On the basis of the results of this study the test could not be considered of any diagnostic value in the determination of strict

[1] All comparisons between groups and comparisons between performances within groups will be made in terms of the standard deviations of the observed differences. The formula used for the determination of the S.D. of a difference is, $S.D._{diff} = \sqrt{S.D._1^2 + S.D._2^2}$ where $S.D._1$ equals the S.D. of one average or percentage and $S.D._2$ equals the S.D. of the compared average or percentage. The S.D. of an average was computed from the formula $S.D._{av.} = \frac{S.D._{dist.}}{\sqrt{N}}$. The S.D. of a percentage was computed from the formula $S.D._{perc.} = \sqrt{\frac{pq}{N}}$ when p equals 1.00 — q and N equals the number of cases in the group. A difference is considered of definite significance only when it equals two times its S.D. ($2 \cdot S.D.$).

central laterality, since no difference was observed between the right and the left handed subjects. It did show some value in presenting evidence of ambilaterality or a lack of definite unilaterality.

The results of this study together with those of *Travis* and *Bryngelson* served to indicate a lack of unilateral dominance on the part of stutterers as compared with normal speakers.

Test C: Motor leads in the homologous paired movements of the two hands

This test makes use of the relative difference between the time of initiation of antitropic movements of bilaterally paired musculatures. The subject is instructed to move both hands at the same time in opposite directions, and a record is made of the hand that shows a temporal lead in the initiation of this movement. *Travis* and *Herren* (97) found that right handed normal speakers with a history of right handedness lead more frequently with the left hand, that left handed normal speakers lead more frequently with the right hand, and that " right handed " stutterers lead more frequently with the right hand. These results were based on a study of 12 left handed normal speakers, 18 right handed normal speakers, and 38 stutterers.

A large high speed kymograph revolving on a horizontal axis was used to record the movements of the hands in this initial study. The subjects were instructed to grasp two styli and stand directly in front of the kymograph. At the command " go " they were to move the styli (supported on two horizontal bars in front of the kymograph drum) first out (abduction) and then in (adduction). A line of reference, or base line, was made after each movement when the drum was stopped. A 100 ~ electrically driven tuning fork furnished the time line between the two lines of hand movement. Only the relative times of initiation of movement were used since the times of arrival " did not show sufficient constancy with themselves or with the starts to be of value ". The total number of leads taken on any given subject varied from 5 to 45, and the average of the total number of leads for the entire group was used in the comparisons. The leads of some

cases were thus weighted much heavier than the leads for other cases. However, the comparisons found in the averages were supported by the data on individual cases which showed that only three out of the 18 right handed normals gave a greater number of right than left leads, ten of the 12 left handed subjects gave more right than left leads, and 28 out of the 38 stutterers gave more right than left leads. It must be kept in mind that movements of the arms from the shoulder, involving the gross musculature, were used in obtaining these results.

Travis and *Bryngelson* (99) determined the precedence of motor lead in 109 right handed normal speakers and 149 stutterers using a somewhat modified technique. The hands were pressed against two break keys which were connected in opposed arms of a bridge circuit with a milliammeter as the recording instrument. The milliammeter would show a deflection if the right key was pressed before the left. They found a large degree of overlapping in the distributions of right leads in the stutterers and normal speakers although there was a definite tendency toward more right leads on the part of the stutterers than on the part of the normal speakers. Adduction of the forearm was the type of movement used in their study.

The apparatus used in this study for detecting differences in the time of initiation of movements of bilaterally paired muscles was considerably different from that used by *Travis* and *Herren* but very similar to that used by *Travis* and *Bryngelson.* The hands were moved against two telegraph break keys with adjustable tension screws. The tension of each key was kept constant by balancing with a given weight. The two keys were placed in opposite arms of a resistance balanced Wheatstone bridge circuit so that the breaking of the right key caused a deflection of the galvanometer to the right and the breaking of the left key caused a like deflection to the left. There would, of course, be no deflection with both keys broken, since both circuits to one pole of the galvanometer would be broken.

The wire tension galvanometer in a Klopsteg chronoscope (without the damping weights) was used to indicate the deflection on a large scale placed on the wall 8 ft. from the galva-

nometer mirror. The center of this scale was marked zero and the bridge balanced so that the hair-line of the light would cover the center of the zero point. The torsion of the galvanometer wire was also adjusted at zero so that the light would come back to zero with both keys broken. The scale was calibrated by placing two break keys from the Klopsteg Fall Apparatus at different distances apart around the circumference of a phonograph turntable revolving at 100 r.p.m. Two, five and ten σ (.001 sec.) units were used on both sides of the point on the scale, making possible the measurement of the extent as well as the determination of the laterality of manual lead. The amount of deflection on the scale was determined by the difference in time between pressing of the right and left keys and the direction of the deflection was determined by which key was pressed first. A lead of one hand over the other as small as 2 σ was easily noted in the deflection of the light. A given amount of right lead was shown to produce the same amount of deflection to the right as the same amount of left lead would produce to the left. In so far as could be observed there was no way by which the apparatus itself could influence the laterality or the extent of laterality in manual leads.

A preliminary test was made with this apparatus using only the laterality of lead as a measure. The sensitivity of the apparatus made the occurrence of " simultaneous " leads sufficiently infrequent as to be disregarded. The subjects were seated at the table as shown in Fig. 2. In this first series the notched board appearing in the illustration was not used. Instructions were given to press both keys at the same time at the command " in " and to release both keys at the command " out ". *E* instructed the subject to keep his hands in contact with the keys and watched the subject throughout the experiment to see that this instruction was carried out.

Six types of movement were used in this preliminary series: (1) the adduction of the arms as in the original study of *Travis* and *Herren*, (2) flexion of the digits with support of the thumb, (3) flexion of the thumbs with support of the digits; (4) adduction of the feet pivoted on the heel, (5) abduction of the feet

pivoted on the heel, and (6) pronation of the feet pivoted on the heel.

Forty trials were given for each movement on each subject. The second and perhaps the third of these movements would probably involve musculature comparable to that used by *Orton* and *Travis* (81) when they found a precedence of action currents

FIG. 2. The leadometer—an apparatus for the measurement of the extent and laterality of motor leads from bilaterally paired muscles.

in the muscles of the right forearm of right handed individuals: the reverse was found to be true in stutterers.

The results from 34 right handed normal speaking subjects with a history of right handedness, other than the subjects in the RN group, showed little more than chance relations between the number of right leads on the right and left sides with a slight tendency to more right leads in the more distal musculature and no tendencies to a preponderance of left leads. Several changes were made in our procedure in an attempt to find the reason for this

discrepancy between our results and those of *Travis* and *Herren.* The movement of the two hands were limited to a more restricted set of muscles. The hands were rested on notches in a piece of wood placed before the keys as shown in Fig. 2.

Movements of flexion of the third and fourth digits were obtained with the hands in the position illustrated in Fig. 2. Movements of extension of the third and fourth digits were obtained with the keys turned around and the hands placed in the notches of the wood with the palms facing each other.

Movements of flexion of the forearm were obtained by removing the notched board and clamping the base of the frame holding the keys to the table. The keys in this position extended a short distance from the edge of the table and were turned down so that they were broken by an upward motion of the hands. The subjects were placed in the chair with the elbows resting against the back of the chair to eliminate motion of the arms from the shoulders. Wrist motion was minimized by having the subjects flex all of the digits with the palms in and the upper portion of the second digit placed in contact with the key. The biceps should be mainly responsible for the motor leads in this situation.

The preliminary series of verbal stimuli for the movement of the hands was given from a position directly behind the subject. In the second series an electrically innervated bell magnet was placed under the table directly in front of the subject in such a way that the arm of the magnet would knock against the table on the make and knock against the metal of the coil mounting on the break. The subjects were instructed to press the keys at the first sound and release the keys on the second sound, thus making the stimulus for movement constant throughout the experiment. A record was taken of the extent and laterality of each lead as it was indicated on the galvanometer scale.

The entire experiment was conducted under two different sets of conditions: (1) the stimulus-response series (S.R.) in which the subject was instructed to press both keys as quickly as possible following the stimulus, the room being silent except for the stimulus to movement, and (2) the distraction series (Dist.) in which the subject was instructed to press the two keys at the same

time following the stimulus paying no attention to the rapidity of the reaction. In the latter series the subject would count aloud from 500 down in steps of three or in some cases in steps of two, in addition to reacting to the stimulus for movement of the two hands. The counting was carried on entirely independently of the stimuli. In addition to this distraction a large ventilating fan making considerable noise was set going during this series. If the differences in experimental situations affect the results of this test, they should show up in these very different sets of conditions.

Twenty-five trials were taken with each musculature in first the S.R. and then the Dist. conditions. Then 25 additional trials were given with each musculature under both sets of conditions with both the order of the musculature and the order of the two sets of conditions reversed. A total of 50 trials was given for each musculature under each set of conditions. Thirty-five right handed normals, 29 left handed normals, 38 ambidextrous normals, and 28 stutterers were tested in this manner.

The average number of right leads for each 25 trials together with the standard deviations of each average showed few significant differences between the four groups of subjects. The left handed normals and stutterers showed a significantly greater number of right (2 to 3 S.D.) leads in the distraction series with the biceps muscle than did the right handed and ambidextrous normals. All groups showed a purely chance average of number of right leads with the flexor muscle and more right than left leads with the extensor muscle, the average preponderance of right leads being about 4.2 S.D.

The correlation between comparable series of trials within the test in terms of number of right leads yielded reliability coefficients (raw) of from .40 P.E.$\pm$.05 for the biceps to .53 P.E.$\pm$.05 for the extensors. Correlation between the number of right leads on the first 25 trials, S.R. series, and a like 25 trials given after a lapse of from one to five months yielded reliability coefficients (raw) of from .41 P.E.$\pm$.09 for the biceps to .69 P.E.$\pm$.06 for the flexors. These coefficients indicated that there was something more than chance operating in the deter-

mination of the number of right and left leads but that the reliability of the test in this form was inadequate for individual clinical diagnosis.

The correlation between the number of right leads in the stimulus-response conditions with the number of right leads in the distracting conditions yielded coefficients of from .42 P.E.±.10 to .63 P.E.±.08 for the flexor and extensor muscles in all groups; this correlation for the mixed group of 126 subjects yielded coefficients of from .58 P.E.±.04 to .60 P.E.±.04 for the three sets of muscles. The stutterers seemed to be more affected, however, by the distraction than the normal speakers when the number of right leads with the biceps was considered as shown by the coefficient of .27 P.E.±.11 between the number of right leads under conditions of distraction and under stimulus-response conditions for the stutterers as compared with coefficients of from .54 P.E.±.01 to .67 P.E.±.07 for the normal speakers.

The inter-correlations between the three sets of paired muscles in terms of the number of right leads showed some rather interesting though puzzling differences between the stutterers and normal speakers. The RN group showed a zero or slightly negative relation between the number of right leads on the flexors and extensors of the digits. This relationship increased to a slight positive with the LN and AN groups (.15 P.E.±.12 and .32 P.E.±.09) and reached the significant positive relation of .50 P.E.±.09 with the stutterers. We have also a flexor and extensor muscle in the biceps and extensors of the digits although they are not paired antagonists. Here again the inter-correlations suggested a higher relationship between these muscles in the stutterers than in the right and left handed normal speakers. When the two flexor muscles were considered, however, there was less relation shown between them, on the basis of the number of right leads, on the part of the stutterers than with the normal speakers (a coefficient of .03 P.E.±.12 for the stutterers as compared to .33 P.E.±.09 for the ambidextrous normal speakers). All of these differences were small but in view of the low reliability of the measures they suggested a basic differ-

ence between the stutterers and all groups of normal speakers which was borne out by the chronaxie studies to be discussed at a later point.

In the use of the motor leads test in the Iowa Speech Clinic a person had been termed right or left in predominance of lead if he had at least 75 per cent of his total number of leads on either one side or the other and he was termed ambidextrous if he presented less than 75 per cent on one side or the other. The percentage of each of our four groups classified in this manner according to the laterality of motor lead showed that the four groups can not be differentiated on the basis of flexor and extensor leads (all groups having had a greater percentage of subjects with a predominance of right leads with the extensor muscles) and the LN group had a slightly greater percentage of individuals with a predominance of right leads with the biceps muscle (27 per cent) than had the RN group (11 per cent). The S group was not classified with the LN group in this measure since it had about the same percentage of individuals with a predominance of right leads as had the RN and AN groups, although the LN and S groups did have a slightly smaller percentage (17 and 18 per cent) of individuals with a predominance of left leads than did the RN and AN groups (26 and 34 per cent). These results were in line with the findings of *Travis* and *Herren* using a comparable set of muscles but the differences were so small that the test in this form could not be considered of much certain value in individual clinical diagnosis.

The extent of lead as well as its laterality was included in our measurements in an attempt to find some aspect of this test which might be useful clinically. Table V presents the average extent of lead of each 25 trials in order as given in the experiment. An analysis of these data indicates the following:

Group differences in average extent of right and left leads

1. Flexor of digits, S.R. series:

In the first 25 trials of this series the S and LN groups had more average right lead than the RN group. In this same series of trials the S group had more average left lead than either of the other groups. The RN group was significantly less than the LN group in amount of right lead but these two groups did not differ in the amount of left lead. In the second 25 trials of this series no significant differences were found between the four groups. No very

significant differences were found between the average extent of right and left lead within any single group in either the first or the second 25 trials.

2. Flexor of digits, Dist. series:

All four groups showed more right lead in the first 25 trials of the distraction series than they did in the S.R. series. All of the normal speaking subjects showed also more left lead in the distraction series but the stutterers seemed to be affected in this series only in the extent of right lead. No other significant differences could be observed between the four groups in this series. In the second 25 trials of this series both the S and LN groups appeared to be more affected in amount of right than left leads by the distracting conditions and even the RN and AN groups showed some difference in this direction. Each of the four groups had a greater extent of right than left lead in this series (Dist.). The LN and S groups had shown a greater amount of right lead than the AN and RN groups as was found in the first 25 trials of the S.R. series but here again the former groups also showed, to a lesser degree, a greater amount of left lead than did the latter groups.

TABLE V. *Average extent of lead in σ for each 25 trials in order of trial*

		RN(35)		LN(29)		AN(38)		S(28)	
Muscle		M	S.D.	M	S.D.	M	S.D.	M	S.D.
Flex.	R	5.5	.7	8.7	.8	6.4	.4	7.3	1.3
S.R.	L	5.6	.8	5.6	.7	5.5	.6	9.1	.2
Dist.	R	8.6	1.5	10.7	1.1	9.4	1.0	11.2	1.6
	L	8.3	.7	10.1	1.4	9.3	.8	8.0	1.7
Ext.	R	11.3	.3	10.7	1.4	11.8	1.7	13.0	1.5
S.R.	L	5.6	.7	5.5	1.1	5.3	.8	6.1	1.2
Dist.	R	13.7	1.3	16.0	1.6	11.7	1.0	17.0	2.1
	L	6.4	.9	9.9	1.3	8.9	1.0	10.5	1.5
Bic.	R	6.3	.9	9.9	1.1	6.4	.8	7.4	1.1
S.R.	L	7.7	1.1	7.8	1.1	8.3	.9	8.6	1.8
Dist.	R	9.1	1.4	11.8	2.0	10.1	1.3	13.2	2.5
	L	7.0	1.7	6.9	1.6	11.4	1.4	9.6	1.2
Bic.	R	10.0	1.0	13.7	1.0	9.9	1.0	16.3	1.6
Dist.	L	10.6	1.1	9.9	1.1	10.9	1.3	8.5	1.7
S.R.	R	5.7	.7	9.6	.6	5.9	1.0	10.0	.3
	L	7.2	1.2	6.5	.6	7.5	1.1	6.5	1.4
Ext.	R	13.7	1.6	12.6	2.2	12.5	1.6	15.0	1.6
Dist.	L	6.6	1.3	9.1	1.6	8.2	.9	9.6	1.3
S.R.	R	11.4	1.6	12.8	1.2	9.2	1.0	10.7	2.2
	L	3.2	.8	5.7	.4	5.0	.7	6.0	1.4
Flex.	R	8.6	.9	11.0	1.0	7.2	1.1	11.3	1.3
Dist.	L	6.3	.7	8.0	1.0	5.8	.7	9.3	.8
S.R.	R	7.8	.9	6.6	1.0	6.3	.7	7.6	1.2
	L	5.0	1.4	6.8	.4	5.6	.7	6.8	.8
Average									
Dist.	R	10.6	1.3	12.6	1.5	10.1	1.3	14.0	1.8
	L	7.5	1.1	9.0	1.3	9.1	1.0	9.2	1.4
S.R.	R	8.0	.8	9.7	1.0	7.7	.9	7.4	1.3
	L	5.7	1.0	6.3	.7	6.2	.8	7.2	1.1

3. Extensor of digits, S.R. series:

No significant differences were shown between the four groups in either the first or the second 25 trials of this series. All groups showed a greater amount of right lead than left lead.

4. Extensor of digits, Dist. series:

In the first 25 trials of this series the S and LN groups had again shown a tendency toward a greater amount of right lead (2.1 S.D.) than the AN and RN groups. Here again the former groups also showed a greater amount of left lead (2.3 S.D.). All groups showed a much greater right than left lead (4.6 S.D. to 2 S.D.). In the second 25 trials of this series no significant differences could be shown between the four groups. All groups showed a greater right than left lead to about the same extent as in the first 25 trials of this series.

5. Flexor of forearms (biceps), S.R. series:

In the 25 trials of this series the LN group indicated a greater amount of right lead (2.5 S.D.) than did the RN group although no difference was shown in the amount of left lead. None of the other differences between the groups were of marked significance. In the second 25 trials of this series, the LN group showed a greater amount of right lead than did the RN group (4.2 S.D.) even more clearly than in the first series. In this series the S group also had a markedly greater amount of right lead than either the AN or RN groups (5.6 and 3.0 S.D.). No significant difference was observed in the amount of left lead although the tendency was in the direction of more left lead on the part of the RN and AN groups. A comparison of the relative amount of right and left leads within groups showed that the RN and AN groups had a slightly greater amount of left lead (1.1 S.D.) and the LN and S groups had a significantly greater amount of right lead (3.6 S.D. and 3.1 S.D.) in this series.

6. Flexor of forearm (biceps), Dist. series:

In both the first and the second 25 trials of this series there was a distinct classification of the S with the LN group as compared with the AN and RN groups. In both series of trials no significant differences were shown between the amount of right and left lead within the RN or AN groups but the LN and S groups showed in every case greater amount (1.2 to 4.1 S.D.) of right than of left lead.

The significance of some of these differences observed in the analysis of the data from individual muscles is lost when only the averages of all muscles are considered. These averages, however, do show (1) that all groups had a greater amount of lead under the condition of distraction than in the more simple stimulus-response situation, (2) that the normal speaking subjects showed a like increase in lead in both the right and left paired muscles averaging 2.3σ, (3) that the stutterers showed about the same increase in amount of lead on the left side ($2.0\ \sigma$) as did the normal speakers but a much greater increase in amount of lead on the right side ($6.6\ \sigma$) under conditions of distraction, (4) that no significant difference was shown between the RN and LN groups, both groups having had a larger amount of right than left lead in both the S.R. and Dist. series of trials, (5) that a slightly less difference in amount of right and left lead was

shown in the AN groups than in the RN and LN groups, (6) and that the S group showed no difference in amount of right and left lead in the S.R. series but a significant difference (2.1 S.D.) between the amount of right and left lead in the Dist. series.

The results of this detailed analysis of the data have led to a possible explanation of the discrepancy found originally between the results of this study and the results of the original study of *Travis* and *Herren*. Our apparatus was much more sensitive than that used in the former study. The laterality of the very slight leads (2 to 5 σ) detected with our apparatus would probably have been influenced to a much greater degree by incidental variables in the experimental situation than would the leads of greater extent. Consequently when we consider laterality of lead alone, we got about the number of right and left leads that would be expected by chance on the flexor and extensors of the digits and only a slight correspondence to the results of *Travis* in the biceps muscle. When the extent of lead is considered, we found evidence, at least with the biceps muscle, of a greater amount of right lead on the part of the S and LN groups as compared with the AN and RN groups, which is in line with the results obtained by *Travis'* methods. *Travis'* results were also obtained by the use of gross musculature such as the biceps used in this study.

The slight indication of a predominance of right lead in the biceps of the LN and S groups in the above tables of average amount and average laterality of leads suggested that a combination of these two measures might emphasize some of the differences found in the separate measures.

TABLE VI. *Average total amount of lead on biceps (50 trials, extent×no.)*

	S.R. series				Dist. series			
	R		L		R		L	
Group	M	S.D.	M	S.D.	M	S.D.	M	S.D.
RN	176	23	264	24	303	41	297	35
LN	280	30	207	23	520	34	250	40
AN	167	22	279	23	292	41	362	38
S	274	30	201	21	454	42	200	18

Calculating the amount of lead in terms of the number times the extent of lead for the biceps, the RN group had 33 per cent (2.7 S.D.) more left than right lead in the S.R. series while the

LN group had shown 26 per cent (2 S.D.) more right than left lead in this series. In the distraction series the RN group showed no significant difference between the right and left hands while the LN group had 52 per cent (5.9 S.D.) more right than left lead in this series. The AN group showed 37 per cent (3.5 S.D.) more of left than right lead in the S.R. series although the difference between the right and left hands in the Dist. series was not significant.

The S group reacted in the same way as the LN group in both the S.R. and Dist. series. The S group showed 26 per cent (2.1 S.D.) more right than left lead in the S.R. series and 55 per cent (5.9 S.D.) more right than left lead in the Dist. series. The difference between the amount of lead with the right and left hands seemed to be equalized in the Dist. series with the RN and AN groups while this difference was doubled in the Dist. series with the LN and S groups.

These results served not only to differentiate the stutterers from the normal speakers but to place the stutterers very definitely in the class with the left handed normal speakers. The stutterers were clearly differentiated also from the ambidextrous normal speakers in this measure since the Dist. series seemed to increase the evidence of left unilaterality in left handed subjects and stutterers but to decrease this tendency in ambidextrous and right handed normal speakers. It might be assumed that under distracting conditions the more basic laterality of neural organizations found expression more freely than in the attentive reaction-time situation.

The reason for the initial discrepancy between our findings and the findings of *Travis* has finally been discovered in the detailed analysis of the conditions of the experiment and the methods of scoring the results. By the use of gross musculatures and by including the extent as well as the laterality of lead, our results not only coincide with the original findings of *Travis* but indicate a still more definite tendency to more right lead on the part of the stutterers and left handed normals and more left lead on the part of the right handed normal speakers than is shown in the former studies. When we use the same method of calculation, however,

on the extensors of the digits, a more distal and more highly differentiated musculature, we obtain very different results.

TABLE VII. *Average total amount of lead on extensors (50 trials, extent×no.)*

	R.S. series				Dist. series			
	R		L		R		L	
	M	S.D.	M	S.D.	M	S.D.	M	S.D.
RN	422	34	121	16	532	53	160	17
LN	435	43	131	19	579	48	166	23
AN	480	52	91	13	525	51	175	21
S	402	42	160	26	544	41	177	28

Calculating the average total amount of lead for the extensors of the digits it was found (Table VI) that the four groups showed no significant differences in the amount of right lead, all of the right leads being greater than the left leads. All of the groups showed about the same amount (22 to 28 per cent, over 2 S.D.) of increase in right leads in the conditions of distraction as compared with the reaction time conditions. The increase in the amount of left lead was greater for the AN group than for the other three groups.

These results were extremely difficult to interpret because of our limited knowledge regarding the neuro-physiological basis of these reactions. The striking differences found between the biceps and the extensor muscles might be interpreted as indicating that the less differentiated proximal musculature reflects the more basic or fundamental nature (from the point of view of the organism itself) of bilateral neural organization while the more highly differentiated distal musculature is influenced to a much greater degree by the imposed conditioning factors common to the environment of all the groups.[2] The distinct classification of the stutterers with the left handed normal speakers on the basis of the total amount of lead in connection with the biceps under both sets of conditions, even differentiating the stutterers very clearly from the ambidextrous normal speakers who are comparable to the group of stutterers on the basis of handedness, suggests the conclusion that our group of stutterers presented a

[2] The common right orientation in writing may contribute to the etiology of these results since the right orientation in writing is imposed upon all groups of subjects and since the effect of this habit would probably be more evident in the distal than in the proximal musculature of the forearm.

dextral superstructure imposed upon a very definite sinistral substructure of bilateral neural organization. The stutterers were thus differentiated from the left handed group of normal speakers in that the latter group presented sinistral tendencies in both substructure and superstructure. The stutterers were also differentiated from the ambidextrous normal speakers in that the latter group presented a more close correspondence between indications of the nature of substructure and superstructure.

Test D: Mirror drawing

Travis was the first to introduce the mirror drawing experiment as a test for " native handedness ". Introducing the report of his first study (**98**) on right handed normal speakers and right handed stutterers, he states that the mirror drawing situation seems especially adaptable to the determination of the basic superiority of the right or the left hand since it confronts the subject " with a relatively new task in which the two hands are on an approximately equal basis ".

A six pointed single line star 4 in. between extreme points was drawn on sheets of paper for the tracings of *Travis*' subjects. Instructions were given to trace the outline of the star, starting in an indicated direction, as rapidly and as accurately as possible. Only the time element of complete tracings was taken into account in the measurements. Twenty-eight right handed normals and 23 right handed stutterers made a first trial with the left hand followed by a series of five trials with the right hand, then made a second trial with the left hand. Fifty-five right handed normals and 48 stutterers made only two tracings, the first with the left hand and the second with the right hand. On comparison of the two hands on the first trial, beginning with the left hand, it was found that 22 per cent of the normals as compared with 86 per cent of the stutterers did better on the second trial with the left hand than on the fifth trial with the right hand. All of these differences were shown to be statistically significant in terms of differences at least three times their P.E.

A significant difference was found between the mean times of the two hands on the first two tracings for right handed normals

but the stutterers were about 4 P.E. better with their left hand even though the first trial was with the left hand in every case. The normals were 2.3 P.E. better in mean time on the first trial with the left hand than were the stutterers. No significant difference in mean time was found between the stutterers and right handed normals on the second trial with the left hand after five trials with the right but the normals were found to be 2.7 P.E. better than the stutterers on the fifth trial with the right hand. No difference was found between the fifth right hand trial of the stutterers and their second left hand trial but the normals were 3 P.E. better in mean time on the fifth right hand trial than on the second left hand trial.

Travis and *Bryngelson* (99) have obtained similar results on a much larger group of cases. Using the same star as that of *Travis* and taking only two trials, the first with the left and the second with the right hand, they found that 35 to 43 per cent of 107 right handed adults did better with the left hand. Eighteen to 32.4 per cent of 110 right handed children did better with the left hand. In a total of 394 mostly right handed stutterers 73 per cent did better with the left hand on the first tracing.

An attempt was made to use the same technique in this study as that used by *Travis* with the exception of the kind of star used in the tracing. It was noticed that with the use of the single line star the number and extent of deviations from the line were so great and varied for different subjects that time alone could not be considered an adequate measure of the efficiency of the performance. A form of star suggested by *R. H. Seashore* was substituted in an attempt to make the error factor sufficiently constant for time measures of efficiency. The same size and form of star was used as that used by *Travis* but rows of circles 2 mm. in diameter spaced 1 mm. apart were substituted for the single lines. These circles were made in stencil by the small " o " of an elite font typewriter and copies were mimeographed for use in this study.

The instructions given were the same as those given by *Travis* with the exception of the additional instruction to try to touch each one of the circles all the way around. This would increase

the accuracy of the tracing by making accuracy a possibility (as it is not in the line star) and by giving the subjects a definite idea of the degree of accuracy expected.

This star was given a preliminary trial in the Iowa Speech Clinic with the assistance of Miss Doris Lampe, a teacher of speech correction in the public schools, who had been trained in giving the mirror tracing test. Forty-one right handed normal adult subjects, other than the RN group used throughout in this study were tested.

The group average time per tracing from the preliminary data was comparable to the results obtained by *Travis* with the single line star in that there was no significant difference between the right and the left hands on the first trials. Forty-three per cent of this group did better with the left hand on the first trials while 61 per cent did better with the left hand on the second trials. These latter results did not correspond closely to the amount of difference between the compared groups reported in *Travis'* first study but they supported the general trend reported by both *Travis* and *Bryngelson.* The indication was that comparable, and perhaps more reliable[3], results could be obtained with the circle rather than with the single line star.

TABLE VIII. *Group averages on each trial of mirror drawing (in sec.)*

	Tracings								
	Left		Right		Right		Left		
Group	M	S.D.	M	S.D.	M	S.D.	M	S.D.	N
RN	150	18	134	14	90	8	70	7	36
LN	133	33	101	23	55	6	55	7	15
AN	113	15	133	15	85	9	63	6	38
S	97	15	121	27	89	14	62	7	19
	Right		Left		Left		Right		
LN	151	23	141	19	95	12	64	8	15

Table VIII shows a continuous increase in ability to trace the star with the left hand when the first trial is with the left hand in the order of groups RN, LN, AN, to the S group whose average time of tracing is only 65 per cent of the average time

[3] *Yoakum* and *Calfee* (111) have shown that mirror drawing with definite points to go through has a much higher reliability than the ordinary continuous tracing. The reliability of the first trial with the average of the next six trials on a form of tracing with definite points in the course was shown to be .93.

of the RN group, a difference of 2.3 S.D. When the LN group was started with the right hand, the average time of tracing on the first trial was the same as that for the RN group, indicating that this was the proper order to make the test for right and left handed subjects comparable.

There was no significant difference indicated between the four groups in the first trials with the right hand. In the second trial with the right hand the LN group was 3.5 S.D. more facile with the *right* hand than the RN group while on the second trial with the left hand there were no significant differences between the four groups. These results served to support the studies of *Travis* and *Bryngelson* in regard to the greater facility, or speed, of the stutterers as compared with right handed normals in tracing the first trial with the left hand, but there was no indication from these results that this was a left handed tendency since there was little significant difference between the right and left handed subjects. *Travis* and *Bryngelson,* of course, did not study left handed normals. In fact the first group of 15 left handed subjects showed a slightly greater facility with the right hand throughout than did the right handed subjects.

TABLE IX. *Percentage of cases better with the left hand in mirror drawing*

Group	1st trials L–R	S.D.	2nd trials R–L	S.D.	N
RN	.50	.08	.75	.07	36
LN	.27	.11	.60	.125	15
AN	.53	.08	.29	.07	38
S	.68	.11	.68	.11	19
	R–L		L–R		
LN	.47	.13	.20	.125	15

Table IX shows a slightly higher percentage (1.3 S.D.) of stutterers who traced the star more rapidly with the left hand on the first trials but a greater difference (2.6 S.D.) is shown between the stutterers and the first group of left handed subjects, the LN group having had a smaller percentage better with the left hand on the first tracing than the RN group. The LN group which was started with the right hand showed the same percentage better with the left on the first trials as did the RN group. In the second trials no significant difference was shown between

the per cent better with the left hand in the RN, LN, and S groups but the AN group seemed to have a smaller percentage than do the others.

The second LN group, tracing in the order R, L, L, R which should be comparable to the L, R, R, L series for the RN group, showed only 20 per cent better with the left hand on the second trials as compared with 75 per cent for the RN group, a differance of 3.8 S.D. There was, therefore, some tendency for the stutterers to do better than the right handed subjects on the first tracing with the left hand but his did not classify the stutterers with the left handed normal speakers since there seemed to be little difference between the left and right handed normal speakers in facility with the left hand. If there is a difference, it seemed to be in favor of the right handed subjects having done better with the left hand than the left handed subjects themselves.

The average times per tracing in Table VIII did, however, indicate some similarity between the S and AN groups in that the AN group also showed a slightly greater facility with the left hand on the first tracings. This difference could not be considered of much significance in the AN group since it was only .9 S.D. as compared with the 2.3 S.D. greater facility using the left hand observed in the S group.

In order to check the possibility of the kind of a star traced influencing the lack of efficiency in the right hand in right handed subjects, the line star as used by *Travis* and *Bryngelson* was used in the testing of 40 right handed adults, 22 women and 18 men. The test was conducted in the same order and with the similar written instructions as with the circle star. Fifty-six per cent of this group were better with the left hand on the first trials, beginning with the left hand. The averages for the four trials ran L, 105; R, 123; R, 85; and L, 40. In this group the average number of seconds for the left hand was 1.1 S.D. less than for the right hand on the first trials.

In order to test the effect of the serial order of trials another group of 75 right handed adults, 35 women and 40 men, was tested in the order R, L, L, R. Eighty-three per cent of this group did better with the left hand on the first trials and 65 per

cent did better with the left hand on the second trial even though the last trial was a tracing with the right hand preceded by three tracings of the star. Right handed subjects seemed to have more difficulty with the right hand than with the left hand in mirror drawing. This result was not surprising in view of the fact that habitual cues to eye-hand coördination inhibit rather than facilitate performance when these cues are completely reversed in mirror drawing. Assuming that cues to eye-hand coördination are more firmly established in connection with the right hand in right handed individuals and more firmly established in the left hand in left handed individuals we would expect the left handed person to be more facile with the right hand and the right handed person more facile with the left in the mirror drawing situation.

How, then, are we to interpret the initial facility of stutterers with the left hand which seems to surpass this facility in either the right or left handed normal speaker? Some clue might be obtained from the average times of the first trials giving a slight indication that the ambidextrous normal subjects reacted similarly to the stutterers in this respect. The ambidextrous normals did not, however, differ from the other normal speakers in the per cent of cases better with the left hand. It might be assumed that the mirror tracing situation presents to the ambilateral neural organization an entirely different set of conditions than it presents to the unilateral neural organization. Where there is an indefinite dominance of either the right or left side, the mirror tracing situation may place the two hands on an equal basis so far as the experimental conditions are concerned, so that the more central laterality of these subjects will manifest itself in greater facility through the motor channels of the more dominant side. The conditions of the experiment may present to the more definitely unilateral neural organization a situation in which the unilaterality itself serves to inhibit rather than facilitate the eye-hand coördination of the dominant side. It must be kept in mind that our groups of left and right handed normal speakers were highly selected extreme cases. On the basis of these assumptions the mirror tracing test may make a significant contribution

to the diagnosis of tendencies toward right or left unilaterality in subjects with an indefinite lateral preference and considerable evidence is presented in this study for the classification of stutterers with the latter type of subject. In order to understand, however, the significance of the tendency of groups of stutterers to show a greater facility with the left hand on initial trials of mirror drawing it is necessary to analyze further the influence of dextrality and sinistrality together with other factors participating in the mirror drawing experiment.

Test E: Visual acuity

Tests of the relative acuity of the two eyes were introduced not because of any expected value as indices of unilaterality but to check the other measures involving the use of the eyes. No tests of the relative sensory efficiency of the two sides of the body have, as yet, shown sufficiently consistent and significant differences to warrant any definite conclusions in regard to this aspect of unilaterality (**105**).

The measures of visual acuity were made in a room with constant illumination. Four acuity charts were used in both monocular and binocular tests. Two of the charts were forms No. 1932 and No. 1933 of the standard *Snellen* type furnished by the American Optical Co. The third chart was *Dr. Edgar J. George's* digit chart and the fourth chart was *Landolt's* broken circle chart No. 985 (F. A. Hardy and Co.). All charts were based on a visual angle of 1 min. The charts were hung on the wall against a black velvet background at the level of the eyes 6 m. from the subject.

The *Parson* manuoptoscope was used to eliminate one eye in determinations of monocular acuity. By inserting "blinds" from either side of the cone, nearly all of the subjects were compelled to use one eye without their becoming aware of the fact. The two eyes were tested individually before the test was made for both eyes. All four charts were used for each eye and for both eyes. The effect of the testing of one eye upon the testing of the other was minimized by testing first with the left eye in

one subject and first with the right in another, by mixing the order of the charts, and by separating the monocular tests by about 5 min. of testing by another of our clinical tests.

The average per cent of normal vision for the four charts was used as the measure of acuity for each subject. The number of subjects better with the right eye than with the left, the number better with both eyes than with either eye, and the average acuity for each eye and both eyes for our four groups of subjects are presented in Table X.

TABLE X. *Monocular and binocular visual acuity*

Group	N	N better with R N	N better with R %	N better both N	N better both %	R av.	S.D. av.	L av.	S.D. av.	B av.	S.D. av.
RN	44	20	45	42	96	.67	.083	.70	.044	.89	.047
LN	29	7	23	25	86	.65	.052	.71	.050	.87	.052
AN	39	17	44	28	72	.73	.033	.75	.035	.90	.037
S	27	12	44	21	78	.67	.062	.62	.058	.79	.071

TABLE XI. *Differences between average acuity in monocular and binocular vision (in terms of diff./S.D. diff.)*

Group	S.D.
RN	3.3
LN	2.7
AN	3.2
S	1.6

Table X shows that the differences between the average acuity of the left eye as compared with that of the right eye can not be considered significant for any of the four groups. The percentage better with the right eye was not significantly different in the RN, LN, and S groups but the LN group had a lower percentage (2 S.D.) of individuals with better right eyes than had the RN group. It is possible that, with the development of more accurate methods of measuring visual acuity, this measure might contribute to a battery of tests for purposes of indicating unilaterality. It did not classify stutterers, however, with the AN or LN groups of normal speakers.

Table X indicates that the difference between the average acuity in monocular and binocular vision is greater for all groups of normal speakers than it is for stutterers. Table XI shows that the percentage of the RN group better in binocular than in monocular vision was greater than the percentage of the S and

AN groups better in binocular than in monocular vision (the respective differences in percentage being 2.2 and 3 S.D.). The two eyes appeared to function more in an additive manner in the binocular acuity of right and left handed normal speakers than they did in stutterers.

Test F: Convergence strength

This test is another one which was included for purposes of checking the results of other eye tests rather than for purposes of getting indications of general neural laterality. Miles (76) mentions this test in his work on eyedness but discards it because of the discomfort usually associated with its administration.[4]

The subject was instructed to fixate the eraser on the end of a pencil held about 30 cm. from the eyes directly in front of the bridge of the nose. The pencil was moved slowly toward the bridge of the nose until one eye ceased to follow in on extreme convergence. The eye that maintained the fixation the longest was termed the dominant eye. Five trials were given. If one eye maintained its dominance in four out of the five trials it was considered the stronger eye. If one eye was stronger in less than four out of five trials or if the two eyes left the position at the same time, the two eyes were considered equal. The results of the administration of this test are shown in Table XII.

Table XII. *Stronger eye convergence strength*

		R		L		Amphi.	
Group	N	N	Per cent	N	Per cent	N	Per cent
RN	43	23	54	7	16	13	30
LN	30	8	27	4	13	18	60
AN	39	9	23	8	20	22	57
S	27	7	26	9	33	11	40

The stutterers were again classed with the AN and LN groups in regard to the number of right eyes dominant and they had 20 per cent more left dominance than did the LN subjects themselves. The difference of 27 per cent (2.5 S.D.) found between the RN and the LN groups was sufficiently large to indicate that

[4] It is interesting to note in this connection that the ophthalmologist usually watches the left more than the right eye when determining the convergence near point in clinical practice.

this test might contribute to a battery of tests for the detection of tendencies to general unilaterality.

IV. Lead eye in binocular convergence and divergence fixations as related to handedness. *Judd,* in a study reported in 1907 (**55**), made the first scientific study of the convergent and divergent movements of the two eyes. He recorded the movements of fixation between fixation points 30 cm. and 55 cm. from the bridge of the nose by use of a high speed moving picture camera. A flake of china white was placed on the eye as a reference point. Differences between the convergence speed of the two eyes were found as great as 75 σ. One eye was found to be more rapid than the other and to differ markedly from the other eye in pattern of movement; one eye seemed to follow the other in a horizontal direction before convergence took place. In this study of three right handed subjects, one subject demonstrated a left lead, another a right lead, and the third no preference for either left or right. No relation was found between the lead eye and acuity, in fact, the less acute eye seemed to be the more rapid in his subjects. He concluded that the lead eye is probably determined by peripheral conditions of muscular balance rather than any general condition related to handedness.

This observation of *Judd* on the difference between the two eyes in coördination movements together with his finding that convergence and divergence movements require a much more complex sensory-motor adjustment than do simple horizontal movements of the eyes suggested the use of photographic records of binocular convergent and divergent adjustments as a part of this study of unilaterality of function. Since the eyes are known to be very sensitive indicators of general conditions of the central nervous system and since binocular coördination is served by one of the most complex of the bilaterally innervated neuro-muscular systems which requires a high degree of unity in function, analogous to the mid-line speech organs, adequate records of their functioning should give some insight into nature of both peripheral and central asymmetry.

Schmidt (**88**), in his study of binocular reading movements, found that the two eyes rarely cover the same distance during the return sweep and during interfixation movements. The lead-

ing eye invariably covers a greater distance than the eye which follows, no matter in which direction the movement may be. The leading eye overshoots and gradually retraces its excess distance while the other eye makes up for its deficiency by moving very gradually in the direction of the point of fixation. The two eyes have a tendency to move in the same lateral direction before making a convergence adjustment.

The Iowa Eye-Movement Camera (to be described shortly in *Science*) was used for the photography. This apparatus made use of the *Dodge* corneal reflection technique. The chief variations from the similar cameras developed by *Miles, Tinker, Dearborn,* and others together with some of the details of our set-up (**93**) are as follows:

1. Split prism lenses were used to divide the beam of light from the cornea of each eye focussing one point on recording paper moving in the vertical direction and the other point on recording paper moving in the horizontal direction. Records of binocular movements in both the horizontal and vertical planes were thus synchronized.
2. The camera was adjusted at a 20° angle of elevation directly in front of the subject's eyes so that the eyes could be photographed from the front without obstructing from view the near and far points of fixation. Since the source of light was reflected to the eyes by means of two first surface mirrors directly in front and below the eyes, the effect of distortions due to reflection was minimized.
3. Time measurements as well as the relative position of the two eyes were indicated on the record by a series of interruptions produced by a chopping disc interrupting the beam of light at its source. These interruptions occurred at the rate of 50 per sec. so that time measurements could be made directly in units of .01 sec. Two teeth were removed from the chopping disc to produce three non-interrupted "spots" on the record at one-half sec. intervals (the chopping disc revolving twice a second). This provided gross time measurements and a check on the relative position of the two eyes throughout the record.
4. Positive records were obtained on Eastman No. 1 sensitive recording paper 1⅞ in. wide.
5. Both vertical and horizontal moving recording papers moved synchronously at constant speeds of from 7 to 9 cm. per sec.
6. The movement of the reflection from the cornea was amplified approximately nine times on the record. The movement of the eyes through a horizontal visual angle of 10 degrees was represented on the record by a movement of 7.8 cm.
7. The head was strapped in a firm head rest with teeth firm in a biting board to minimize head movements.
8. A mercury filled neon signal light was placed in such a way at the rear of the camera that a slit of light was focussed across the intersection of the vertical and horizontal films for the purpose of aiding in matching the two films and marking the incidence of visual stimuli.

The fixation points were especially constructed gas discharge tubes made by

a local neon sign manufacturer to produce an instantaneous initiation of the stimulus. They were shaped as illustrated in Fig. 3, the points drawn out to an inside diameter of 1.5 mm. The entire tubes were painted with opaque black paint. An area of 5 mm. by 2 mm. was exposed by removing some paint near the tip of the front portion of the near point while an area 1.5 mm. by 10 mm. was exposed in like manner for the far points.

The lights were filled with neon and crypton gas discharging in mercury vapor in proportions intended to produce white light. The near point had a slight greenish cast, probably due to some oxidation of the mercury, while the far point had a slight bluish cast due to an excess of crypton. It just happened that this difference in color provided an excellent means of distinguishing

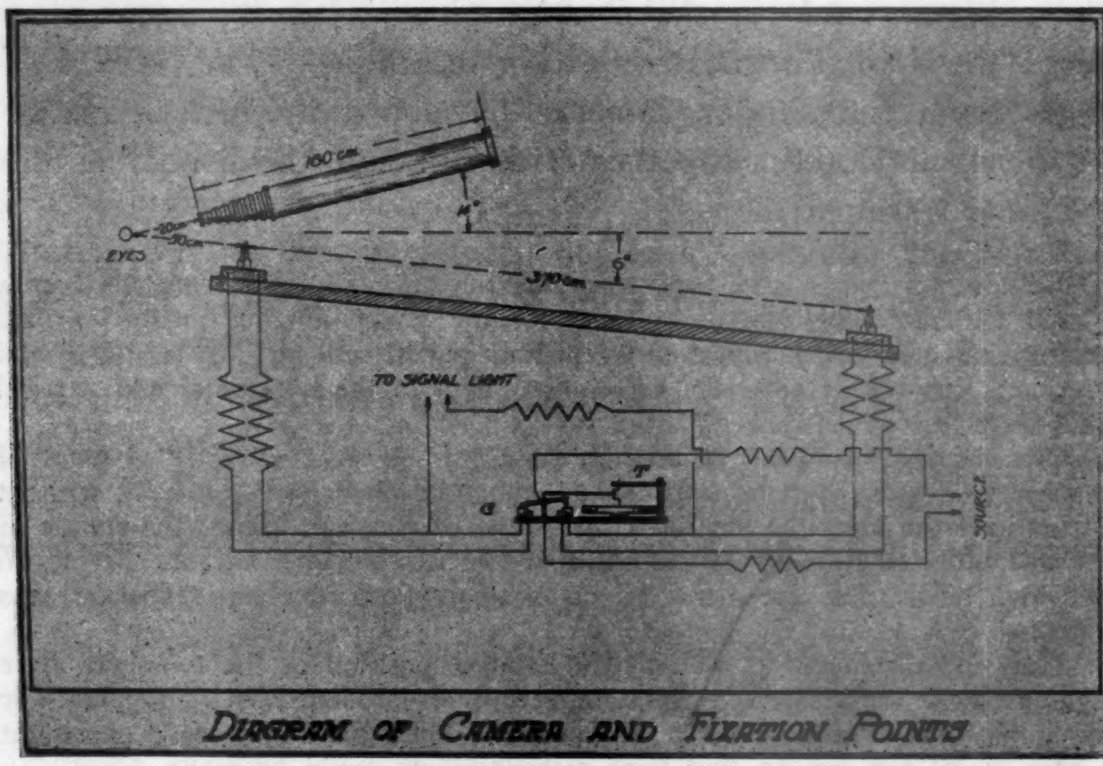


FIG. 3. Diagram of camera and fixation points.

between the near and far doublings when the subject was unable to perceive the distance in a completely darkened room. Resistances were placed in series with the near light until the brightness of the two lights was equalized according to the judgment of several observers from position in the head rest.

Fig. 3 gives, diagrammatically, the position of the fixation points relative to the camera and the subject together with the mechanism for alternate illumination of the near and far points. The lights were aligned at an angle of 6° below the horizontal of the eyes in order that the eyes might move more nearly in their natural orientation. The near fixation point was 50 cm. from the cornea making the degree of convergence at this point about 2 m. angles.[5] The far point was 420 cm. from the corneas, which would make the degree of convergence at this point about .24 m. angles.

An induction motor driven phonograph turntable with a cam-shaft attached was used to regulate the alternation of the fixation points. A lever arm attached

[5] A meter angle is the angle of turning of the visual axis of each eye required to fixate at 1 m. distance on a line perpendicular to the imaginary line joining the centers of rotation of the eyes (the latter mean distance being 64 mm.).

to this cam-shaft moved a rocker switch back and forth making and breaking contacts in four mercury cups. Four contacts were used because it was found that the breaking of only one contact to a gas discharge tube does not completely eliminate the glow. A wide range of speeds, each of which could be maintained very constantly, was controlled by the governor on the phonograph motor.

Contacts for the signal light were made by shunting across one side of the lead to the near light and the other side of the lead to the far light, as is illustrated in Fig. 3, making it possible for it to flash only when the contacts were made in both of the two mercury cups on opposite sides of the rocker switch. Since the resistance in the small mercury filled neon glow lamp used for the signal light was much less than that in the fixation lights the fixation lights would go off during the period of the flash of the signal light. The contacts were adjusted in the mercury cups so that the signal light would flash for approximately 5 σ between the lighting of each fixation point. The end of the flash of the signal light marked on the record the exact time of initiation of each fixation stimulus.

All subjects were attached to the head rest with their eyes in the same position relative to the near fixation point. The far point was aligned with the near point and with a point midway between the two eyes. The room was then darkened with the exception of beams of light directed to the eyes from the arc light used in the photography. The near fixation point was illuminated for a short time so that the subject could become accustomed to the convergent fixation adjustment, and then the far point was illuminated long enough for the subject to become adjusted to the divergent adjustment. The near and far points were then illuminated alternately at a very slow speed, over 1 sec. per fixation, with the instructions to look at each light as it came on. The speed of alternation was then increased until a speed was reached at which the subject reported he could no longer bring the doublings together. A speed of alternation just below the speed at which convergent or divergent adjustments broke down was used during the eye photography.

After the subject had made several convergent and divergent adjustments at his maximum speed, a photographic record was made of 30 alternate near and far fixations. At the beginning of the study records were also taken of horizontal fixations between two points placed 15 cm. apart, 40 cm. from the eyes, but these records were discontinued when it was found that they did not yield very marked indications of unilaterality in binocular movement.

The subjects used in this part of the study were selected from the four groups used throughout in other tests. Readable records were obtained from 23 of the group of right handed subjects, 22 of the group of left handed subjects, 17 of the ambidextrous group and 18 of the group of stutterers. The records were read both for the speed of movement of the two eyes and for the pattern of divergent or convergent adjustment. An indication of the relative speed of movement was obtained by reading the time on the record from the initiation of a deviation from one adjustment, following the stimulus for the next, to a point at which the eye reaches, or exceeds, an imaginary line between the fixation point and the fovea. This point is illustrated in Fig. 4

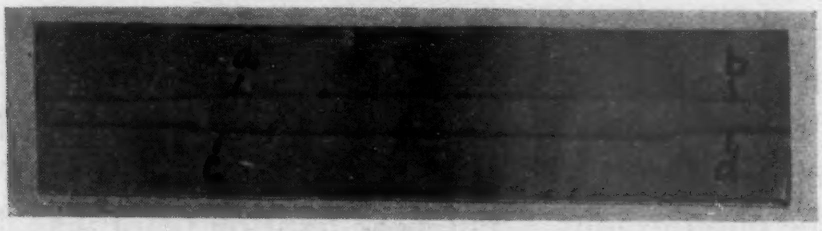


FIG. 4. Horizontal movements of the two eyes in divergent and convergent fixations. (a) Point at which right eye reaches its line of fixation on divergence. (c) Point at which right eye reaches its line of fixation on convergence. (b) and (d) Like points for left eye. The thinning of the record at (a) and (b) is caused by the vertical movement associated with the horizontal fixation adjustment. The small dots in the record represent .02 sec. The dashes in the record are spaced at .5 sec. intervals. The two markings at the top of the record indicate the beginning of the stimuli for fixation. It will be noted that the first fixation has anticipated the stimulus. The divergent fixation is symmetrical while the following convergence is a left dominant pattern. The upper line is the right in all records of horizontal movements.

for the right eye at points *a* and *b* and for the left eye at points *c* and *d*. If there was a tendency for the right eye, for example, to "lead" or inhibit the movement of the left keeping it from reaching its fixation adjustment until the right eye had reached or exceeded its divergent or convergent position, it should have a shorter time as indicated by this method of reading the records. This did not give the time of complete adjustment to the fixation point, for the exact location of the place on the record where complete adjustment to the fixation point was first made, was, in many cases, practically impossible. In reading the records a line was drawn through the parts of the record which were parallel

with the edge of the paper and which seemed to be in line with the position of the eyes in any single fixation adjustment. This line is taken as the imaginary line between the fixation point and the fovea.

Table XIII presents the average speed of movement of each eye in the convergent and divergent adjustments of our four classes of subjects.

TABLE XIII. *Average speed of movement of the two eyes in convergent and divergent fixation (in sec.)*

	Convergence				Divergence			
	R		L		R		L	
Group	M	S.D.	M	S.D.	M	S.D.	M	S.D.
RN	.36	.03	.41	.03	.38	.03	.39	.035
LN	.31	.04	.35	.03	.33	.03	.43	.04
AN	.32	.04	.33	.05	.30	.04	.31	.04
S	.49	.06	.53	.07	.48	.05	.55	.045

No significant differences between the right and left eye in speed of movement in convergent adjustments is shown in any of the four groups. The stutterers seemed to have been considerably slower in this adjustment (1.9 S.D. to 2.5 S.D.) than the normal speaking subjects. In the divergence movements of the LN group the right eye was 23 per cent faster (2 S.D.) than the left, while there was no significant difference between the speed of movement of the two eyes in the RN and AN groups. The stutterers showed the same tendency as the LN group only to a lesser degree.

The patterns of fixation adjustment were classified as (1) right dominant, (2) left dominant, and (3) symmetrical, that is, no dominance indicated. When there was any indication on the record that the right eye was moving towards the position of its next fixation adjustment and carrying the left eye with it away from the direction of the left eye's next fixation position, the pattern was classified as right dominant. If the left eye seemed to carry the right eye the pattern was classified as left dominant. Right and left dominant fixation patterns are illustrated in Fig. 5. If there was no indication of a lead in either eye, the pattern was classified as symmetrical. Symmetrical patterns are illustrated in Fig. 6. In practically every instance of a break in the ability

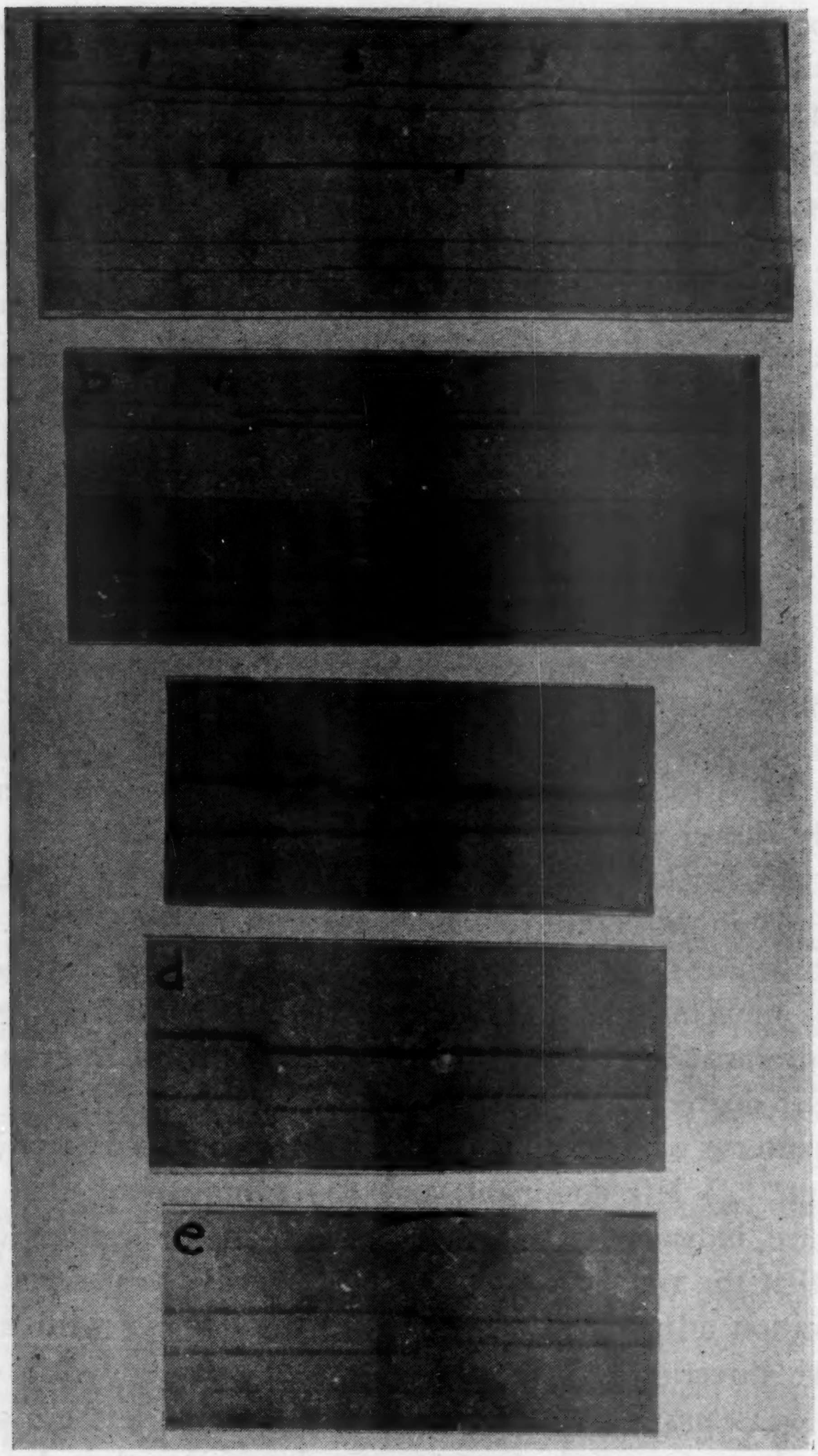


FIG. 5. Right and left dominant fixation patterns. Upper half of double records horizontal movements, lower half of double records vertical movements. Single records only horizontal movements. (a-1) a left lead convergence, (a-2) a right lead divergence, (a-3) a left lead convergence, and (a-4) a symmetrical divergence with associated vertical movement; (b-1) marked right lead convergence overshooting line of fixation,

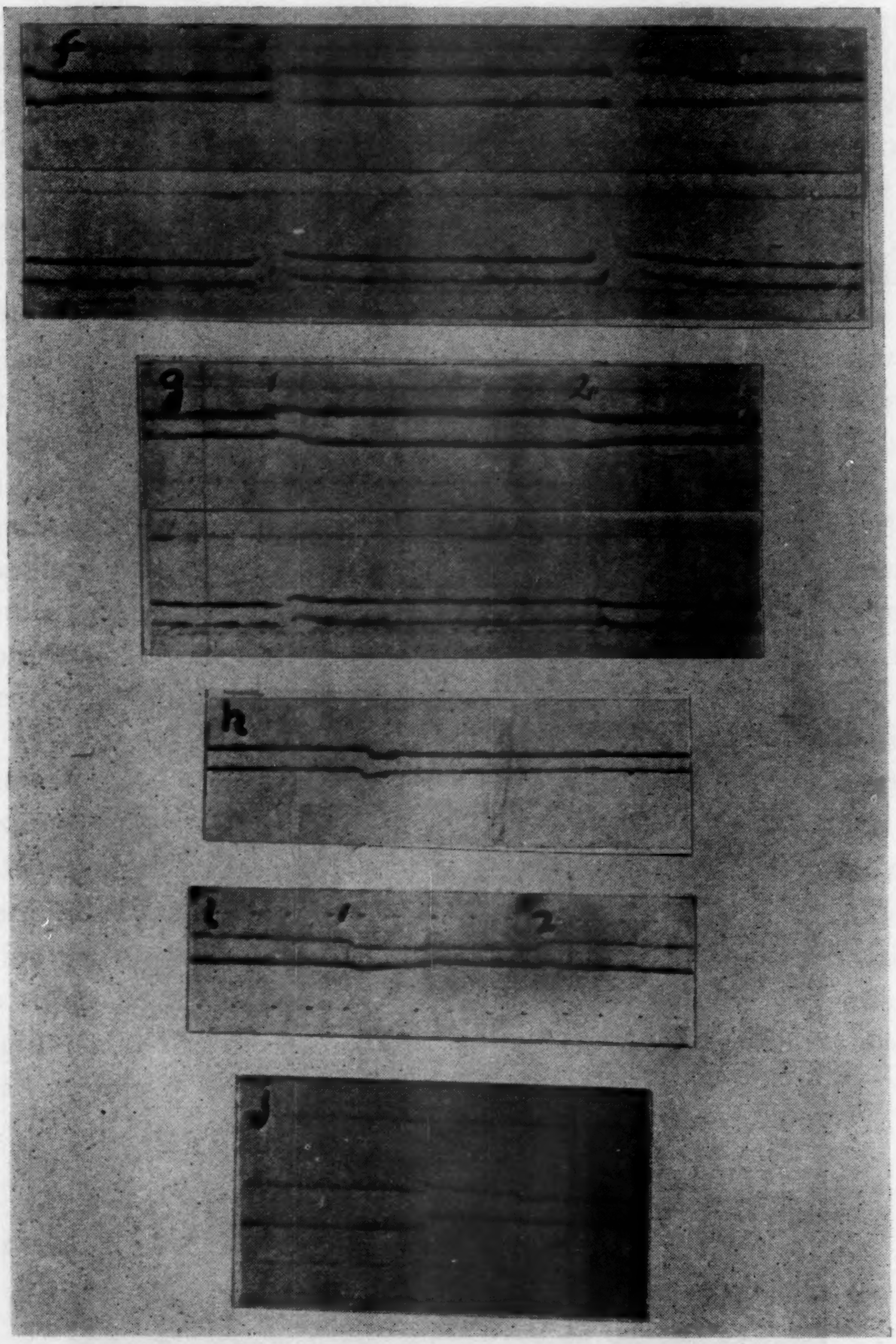


FIG. 5 (cont.)

(b-2) right lead divergence; (c) marked right lead convergence; (d) and (e) extreme forms of right lead convergences; (f-1) right lead divergence with blink, (f-2) blink preceding right lead convergence; (g-1) right lead divergence followed by (g-2) symmetrical convergence; (h) right lead convergence; (i) right lead convergence and divergence; (j) marked left lead convergence.

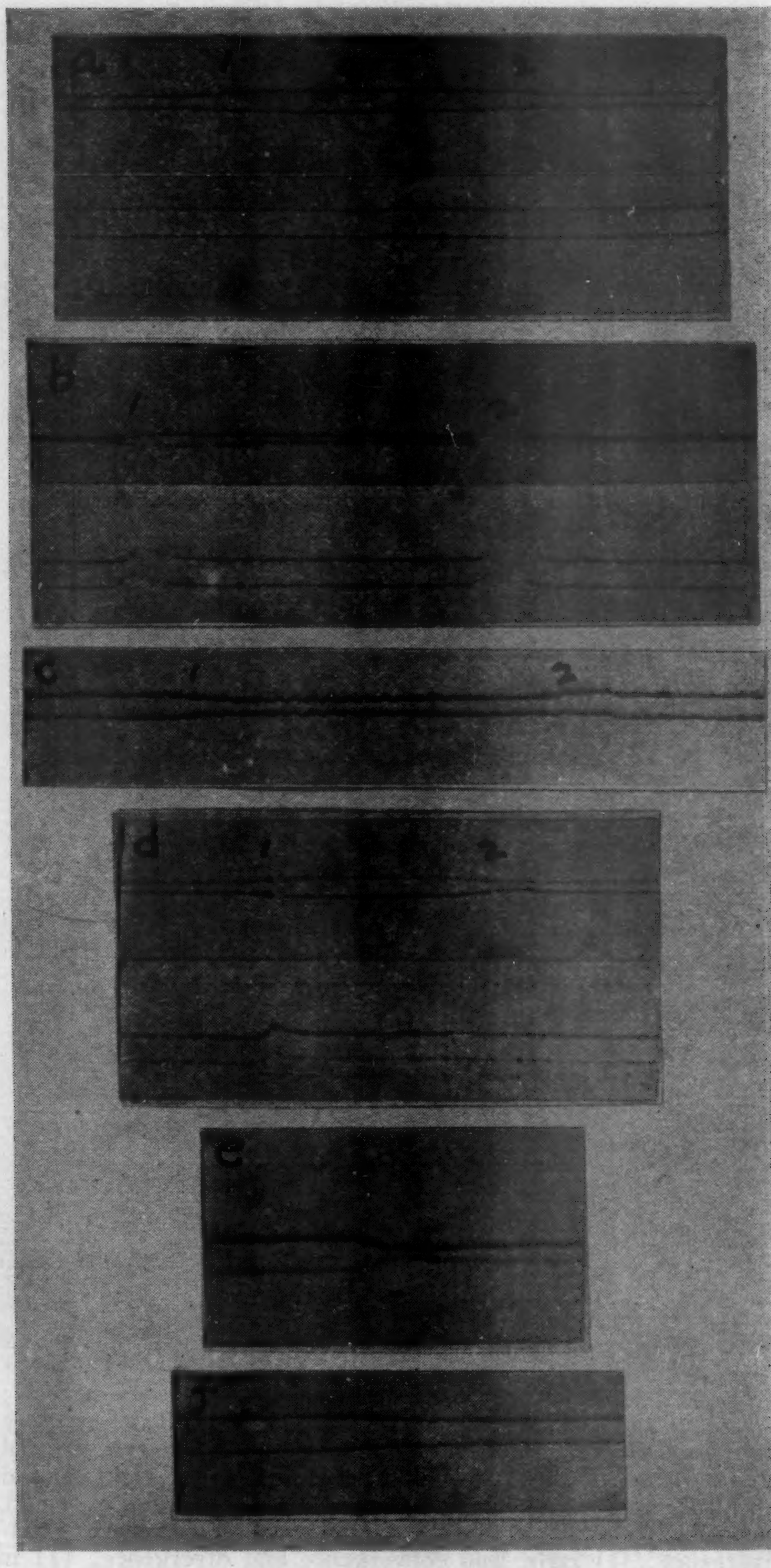


FIG. 6. Symmetrical fixation patterns. Upper half horizontal, lower half vertical movements in (a-1) divergence and (a-2) convergence with no vertical movement; (b) characteristic vertical movements and complete closing of eyes associated with (1) divergence and (2) convergence movements; (c-1) convergence with tremors at 14 per sec. followed by (c-2) right lead divergence; (d-1) divergence with associated upward vertical twitch followed by (d-2) convergence with no vertical movement; (e) and (f) extremes of symmetrical convergences.

to continue convergence and divergence fixations the eye that gave evidence of dominance in pattern would continue to fixate the near and far point alternately while the other eye moved horizontally parallel to the dominant eye. This gives additional evidence to justify the classification of right or left dominance on the basis of pattern indications.

In some cases these three classes of patterns were easily detected by watching the movements of the two eyes from the focus of their "high lights" on the ground glass at the rear of the camera. In the dominant patterns, the dominant eye seemed to snap in or out of its position as though it were released from a trigger while the other eye would either move more slowly and continuously to its fixation position or would give a rapid jerk in the same horizontal direction as the dominant eye before its slow convergent or divergent movement. In the symmetrical patterns both eyes moved at the slower rate of speed in the direction of their next fixation adjustment.

In reading the records it was noticed that in some fixations there seemed to be an alternation in the lead eye within a single fixation adjustment, one eye pulling the other out and then the other eye pulling the first one in, or *vice versa*, until the convergent or divergent adjustment was made. This alternation in dominance is illustrated in Fig. 7. These patterns were classified as right-left dominance (RL) when the first eye to lead was the right eye and left-right dominance (LR) when the first eye to lead was the left eye.

TABLE XIV. *Average per cent occurrence of fixation patterns*

	Convergence					Divergence					
Group	R	L	S	RL	LR	R	L	S	RL	LR	N
RN	.29	.19	.51	.01	.00	.29	.34	.34	.02	.01	23
LN	.26	.11	.60	.03	.00	.49	.12	.37	.01	.01	22
AN	.20	.34	.44	.01	.01	.31	.30	.35	.02	.01	17
S	.18	.15	.61	.04	.02	.37	.15	.33	.14	.02	18

In the analysis of fixation patterns we find little difference of significance between the four groups in the convergent fixations corresponding to a like finding in the speed measurements. There was a slight indication that the AN group had fewer (1 S.D.)

symmetrical patterns than did the LN and S groups and a greater percentage of left patterns (1.6 S.D. and 1.8 S.D.) than did the latter groups.

In the divergent patterns there seemed to be few differences between the four groups in per cent of symmetrical patterns but some very interesting differences between the groups in regard to the relation of right and left lead patterns. The AN and RN groups had about the same per cent of right and left lead patterns. The LN group, however, had 75 per cent (3.3 S.D.) more right

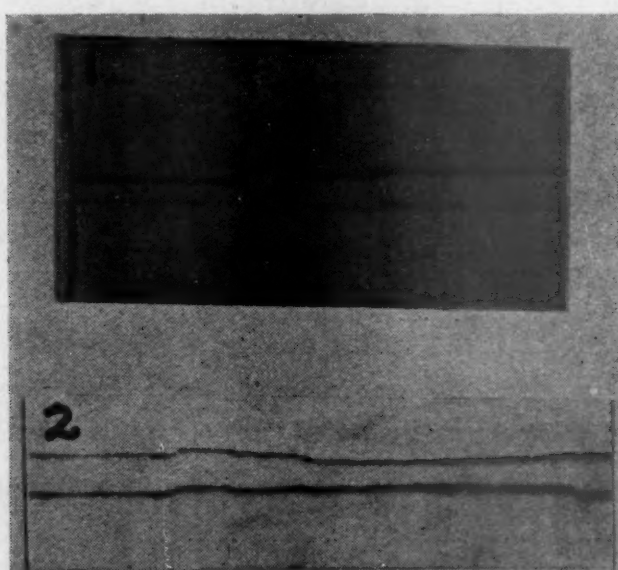


FIG. 7. Right-left lead patterns; alternating laterality of dominant eye. 1—First right eye (upper line) moves beyond its line of fixation pulling the left eye (lower line) with it, then left eye moves beyond its line of fixation pulling right eye with it. (2) First left and then right eye leads in this convergence pattern.

than left lead patterns, which again placed the S group in the class with the LN group since the S group has 59.5 per cent (2 S.D.) more right than left lead patterns. The S group, however, differed from the LN group, and from all of the normal speaking groups, in the percentage of alternate right-left patterns in the divergent fixations while none of the other groups showed any significant amount of this type of pattern.

The tendency to more right lead patterns on the part of the left handed subjects and the tendency to more left lead patterns on the part of the right handed subjects in the divergent fixations corresponded with a like tendency in the motor leads test with

the biceps. This reversal in expected laterality indicated in both of these tests of very different musculatures and of very different types of movement suggests some basic general neural organization responsible for both phenomena, the nature of which is most difficult to determine. It is also interesting to note that the results on the convergent movements of the eyes corresponded to some degree with the results on the more highly differentiated musculature used in the motor leads test since the convergent adjustment was considered to be more highly differentiated, *i.e.*, less of the reflex type of adjustment, than was the divergent adjustment.

The higher percentage of alternate leads in pattern of divergent movement on the part of the stutterers as compared with the normal speaker suggests that there is a tendency to an alternation in the peripheral expression of unilaterality on the part of some stutterers.

V. Asymmetry of function in the perception of phi phenomena between points of fixation and homonymous and heteronymous doublings. The phi phenomenon, that is, the perception of movement between two spatially separate areas of stimulation when the two areas are stimulated alternately at a certin frequency, has been the subject of several investigations chiefly in the field of vision. It is responsible for the movement perceived in moving pictures and electric signs. This phenomenon was utilized in this study to obtain indications of unilateral dominance in the field of perception.

Observation by the writer, who is right handed, of the rapid alternation of the near and far fixation points described in the preceding chapter, revealed that movement was perceived between the point fixated and one of the homonymous or heteronymous doublings on either side. Further observation showed that the movement was between the near point and the right one of the far doublings when the near point was fixated and also to the right of the near doublings when the far point was fixated. The direction of movement could not be changed even when the head was moved so that the point fixated was closer to the left than to the right doubling. The same results were obtained from another

right handed subject. Two left handed subjects were then examined and found to see the movement always to the left of the point fixated. These results indicated that this phenomenon might be used to obtain indications of unilateral dominance in perception.

When the near point (A in Fig. 8) was fixated and the near and far point alternated (B in Fig. 8) at frequencies of from 2 to 4 per sec., the retinæ of the left and right eyes were both

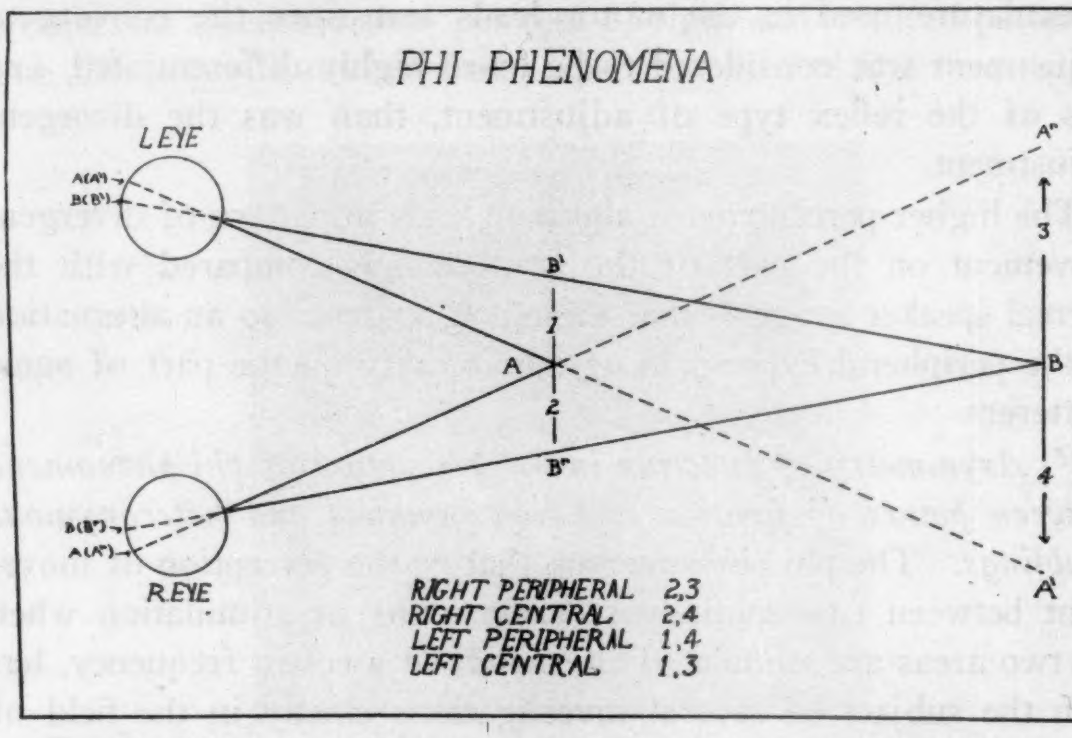


FIG. 8. Diagram to illustrate various types of dominance for the phi phenomenon.

stimulated on the foveal area by point A and on non-corresponding points by point B.[6] Homonymous doublings of point B were perceived approximately in the plane of the point of fixation at B^l and B^r. The far point of light causing doubling B^r was seen with the right eye but stimulated the left half of the retina and consequently stimulated the left occipital lobe, since the left halves

[6] Assuming the distance from the nodal point to the retina to be approximately 14.5 mm. with the near and far points arranged as described in the preceding chapter, the distance between the foveal point of the retina stimulated by the point fixated and the point on the retina stimulated by the point producing the doublings was about .9 mm. Assuming the radius of the foveal area to be less than that of the macula lutea which is approximately .5 mm. it is safe to assume that the stimulation for movement between the point fixated and the doublings occurred in one or the other half of the retina outside of the foveal area.

of both retinæ are connected through the optic chiasma to the left hemisphere. The same point of light causing the doubling B^l was seen with the left eye but stimulated the right half of the retinæ directly connected with the right occipital lobe, since the right halves of the retinæ are connected through the optic chiasma to the right hemisphere. Since the two points perceived on either side of the fixation point A were produced by a single stimulus at point B, there was equal stimulation for the perception of motion both to the right and left of the fixation point. If the motion was perceived in only one direction, to the right, for example, it indicated either a right eyed dominance or a left hemispherical dominance in the perception. If the motion appeared to the left, there must have been a left eyed dominance or a right hemispherical dominance in the perception.

When the fixation was shifted to the far point, point B, the entire system of relations was reversed. Point B now stimulated the foveal area in both eyes and point A fell on heterologous points of the two retinæ. Point A was consequently perceived as two points A^r and A^l on either side of the point fixated and approximately in the plane of the latter point. The doublings were now heteronymous, the doubling appearing on the right having been seen with the left eye and the doubling appearing on the left having been seen with the right eye. The near point of light, causing doubling A^l appearing to the right of the fixation point, stimulated the left half of the left retina directly connected with the left hemisphere. The same point of light, causing doubling A^r appearing to the left of the fixation point, stimulated the right half of the right retina directly connected with the right hemisphere. Here, as in the fixation of the near point, stimulation was equal for the perception of motion both to the right and to the left of the point fixated. If the motion was perceived to the right, there was indication of a dominance of either the left hemisphere or of the left eye while if the motion appeared to the left, there was indicated either a dominance of the right hemisphere or of the right eye.

There are four possible combinations of movement when first the near point and then the far point are fixated: (1) There may

be a movement to the right of the near fixation and to the left of the far fixation indicating a dominance of the right eye in perception but no central dominance since in the first instance the left half of the right retina is receiving the stimulus which appears dominant in perception and in the second instance the right half of the right retina is receiving the stimulus perceived as dominant. This combination is represented in Fig. 8 by movements 2 and 3 and is termed right peripheral dominance. (2) There may be a movement to the left of the near fixation point and to the right of the far fixation point indicating a dominance of the left eye in perception but no central dominance since, in the first instance the right half of the left retina is receiving the stimulus which appears dominant in perception and in the second instance the left half of the left retina is receiving the stimulus which appears to dominate. This combination is represented in Fig. 8 by movements 1 and 4 and is termed left peripheral dominance. (3) There may be movement to the right of the near fixation point and also to the right of the far fixation point indicating a right central dominance and no peripheral dominance since, in the first instance the right eye receives the stimulus which appears to dominate and in the second instance the left eye receives the stimulus which appears to dominate but in both instances the impulses to the left hemisphere appear to dominate in perception. This combination is represented by movements 2 and 4 in Fig. 8 and is termed right central dominance. (4) Finally, there may be a movement to the left of the near fixation point and also to the left of the far fixation point indicating a left central dominance and no peripheral dominance since in the first instance the left eye receives the stimulus which appears to dominate and in the second instance the right eye receives the stimulus which appears to dominate while in both instances the right hemisphere receives the impulses which appear to dominate in perception. This combination is represented in Fig. 8 by movements 1 and 3 and is termed left central dominance.

The speed of alternation of the near and far points was controlled by the governor of the electric phonograph motor described in the former chapter. A stroboscopic disc was placed on the

turntable of this motor and a red neon tube was fixed directly above the disc. A 100 ~ electrically driven tuning fork placed in circuit with the primary coil of the transformer used to light the neon tube caused the frequency of the light's flashing to be constant at 100 per sec. The speed of the turntable could thus be determined in units of .05 rev./sec. by reading the number of the stationary line on the stroboscope disc.

The fixation points were screened from view while the subject was being adjusted in the head rest. The room was then completely darkened except for the glow of the neon light above the stroboscope disc, which was shielded from the direct view of the subjects. The far fixation point was then illuminated and the subject instructed to look at this point and to keep looking at it throughout the first part of the experiment. The lights were then alternated at a frequency of about 4 or 5 per sec. until adjustment of the fixation point was made so as to cause it to appear exactly in the center between the two doublings and in the same vertical plane. With this procedure the doublings of the near point seen upon fixation of the far point were seen distinctly as two lights on either side of the fixation point at the same distance as the fixation point. The subjects perceived the doublings in front of the far point or, upon fixating the near point, behind the near point only when they obtained some sort of cue as to their source.

After all adjustments were made the subject was instructed to keep looking at the fixation point and to report any tendencies for it to move upon its appearing or disappearing. The frequency of alternation was then lowered until the subject reported a motion either of the point fixated or of the doublings. The subject was then asked to describe in full the character of the motion as to its direction and relation to the doublings and the fixation point.

There was considerable individual difference in the ability to see this form of the phi phenomenon. Some individuals would remark upon the motion of the alternating stimuli even before all the adjustments were made and before instructions were given to observe their motion. Other subjects were unable to see any

motion even after it was suggested rather strongly and the whole range of speeds of alternation was tried. There is probably some significance to these wide individual differences since the perception of the phi phenomenon under these conditions seems to depend upon a dominance of one or more elements in perception, unless the motion is perceived both to the right and the left at the same time, and this was seldom found to be the case with normal subjects.

There were also large individual differences in the nature of the motion perceived. Some would describe the motion as though " a pendulum were swinging from one light to the other and then back again ". Others described the motion in terms of " a black cloth or shutter closing over the light from one side ". Others thought that there was actually a glow of the point fixated passing over to one of the doublings, and for others it seemed as though " a shadow moved between the two lights ". For some subjects one of the doublings seemed to move toward the point fixated while the latter point moved very little. For others the point fixated " jumped into " one of the doublings but the doubling remained relatively stationary. In a very few cases both of the doublings appeared to move horizontally parallel to each other, one of the doublings going toward the fixation point and the other doubling going away from the fixation point. Only four of the entire 93 subjects tested saw the fixation point split into two and go " into " both of the doublings on either side. Six of this group reported that both of the doublings on either side of the fixation point seemed to " jump in a little " toward the center when they went off.

The subjects tested were classified according to the type of dominance their reports indicated. This classification is as follows:

1. Right peripheral dominance; including any significant indication of motion between the near point fixated and the right far doubling and between the far point fixated and the left near doubling.

2. Left peripheral dominance; including any significant indication of motion between the near point fixated and the left far doubling and between the far point fixated and the right near doubling.

3. Peripheral ambilaterality; including either the inability to perceive any motion at all or the perception of motion to the right on both near and far fixations.

4. Right central dominance; including any significant indication of the perception of motion between the points fixated, both near and far, and the right doubling.
5. Left central dominance; including any significant indication of the perception of motion between the points fixated, both near and far, and the left doubling.
6. Central ambilaterality; including either the inability to perceive any motion or the perception of motion to the right of one fixation point and to the left of the other.

There should probably be a special classification for the subjects who fail to see any motion at all, since this type of ambilaterality is very different from the other types included under this classification but there are so few who fail to see the motion that they may be treated individually.

The percentage of each group whose reports fall in the respective classification is given in Table XV.

TABLE XV. *Group percentages in each of six classifications of dominance in perception of the phi phenomenon*

	Peripheral			Central			
Group	R	L	A	R	L	A	N
RN	.13	.16	.71	.48	.16	.36	31
LN	.18	.27	.55	.00	.41	.59	22
AN	.29	.12	.59	.12	.12	.76	24
S	.06	.25	.69	.00	.06	.94	16

An analysis of the above table leads to the following conclusions:

1. Forty-eight per cent of the RN group presented right central dominance and peripheral ambilaterality as compared with no right central dominance in the LN and S groups.
2. There was no significant difference between the amount of right and left peripheral dominance in the RN group while there was 67 per cent (2.8 S.D.) more right than left central dominance.
3. There was 51 per cent (3 S.D.) more peripheral than central ambilaterality in the RN group.
4. There was no significant difference between the amount of right and left peripheral dominance in the LN group while there was 100 per cent more left than right central dominance; there having been no right central dominance in the LN group.
5. There was no significant difference between the amount of peripheral and central ambilaterality in the LN group.
6. There was no significant difference between the amount of right and left peripheral dominance nor between the amount of right and left central dominance in the AN group.
7. There was some indication (1.5 S.D.) that the AN group had a greater amount of central than peripheral ambilaterality.

8. There was some indication (1.7 S.D.) that the S group had more left than right peripheral dominance although this group had very little of either.

9. The S group had a negligible amount of either right or left central dominance.

10. The S group had 27 per cent (1.6 S.D.) more central than peripheral ambilaterality.

11. The RN group had about the same amount of right central dominance as the LN group had left central dominance.

12. The LN group had more central and less peripheral ambilaterality than did the RN group.

13. The LN and RN groups had more central dominance than had the AN or S groups.

14. The four groups in order of increasing amount of central ambilaterality are: RN, LN, AN, and S.

Seven of the 19 stutterers tested were unable to see the movement on one or both of the fixation points, while movement was perceived by all of both the RN and LN groups. Two out of the 28 ambidextrous subjects were unable to perceive the movement. One subject in the RN group and three subjects in the LN group saw movement between the point fixated and both of the doublings. Two subjects in the AN group and five subjects in the S group saw movement between the point fixated and both of the doublings.

These results seem to indicate that unilaterality in general neural organization is expressed in the field of perception as well as in the field of manual preference. The phi phenomenon test of both peripheral and central dominance clearly demonstrated the lack of unilaterality on the part of stutterers as compared with right and left handed normal speakers, and it showed a tendency on the part of the stutterers to have more ambilaterality than the ambidextrous normal speakers. It differentiated further between the ambidextrous normal speaker and the stutterers in that the stutterers showed a tendency to more left peripheral dominance while the ambidextrous normal speakers showed a tendency to more right peripheral dominance.

On the basis of these results the diagnostic value of this test with individuals who had uncertain unilateral tendencies lies in the indications obtained from the laterality of the peripheral dominance, *i.e.,* if an individual had a left peripheral dominance it may have been some indication that he had a slight tendency to a left laterality of neural organization.

VI. Relative excitability of homologous paired muscles. The work of *Lapicque* and his associates has established the importance of the function of time in measures of tissue excitability. Interpreting his own researches and those of several other investigators in the field of chronaxie research, *Lapicque* attempts to explain all of the functions of the nervous system in terms of systems of chronaxie values, a sort of resonance within the nervous system (**65**). If the nervous system does operate on the principle of resonance as reflected in chronaxie measurements, these measurements on the two sides of the nervous system should contribute to our understanding of the nature of bilateral neural organization.

Chronaxie is the term applied by *Lapicque* in 1909 (**64**) to the time factor involved in minimal thresholds of excitability for any excitable tissue. Several early physiologists, including *Fick* (1863), *Bruck* (1867), and *Engelmann* (1870), observed that the *DuBois Reymond* law, which states excitation is produced only by the variation in intensity of current and is not related to the time of passage of the current, does not hold for short durations of current (**63**). *Hoorweg,* in 1897, was the first to formulate a definite law to express the duration element in the excitation process (**10**). By use of the discharge of condensers, *Hoorweg* found that the minimal voltage necessary to produce a response was raised when the capacity was diminished. At high capacities, however, the minimal voltage remained the same with changes in capacity. From his experimental results he found that as the capacity necessary for excitation decreased, the voltage increased continually, the quantity (CV) decreased regularly, and the energy (.5 CV^2) decreased at first and then increased.

Weiss, in 1901 (**107**), recognized the limitations of condenser discharges in the measurement of the time element of excitation because " on ne sait a quel moment on doit considerer le decharge comme termiee ". In order to get rectangular waves of very short duration he devised the " Rheotome balistique ". A bullet from a gun of known speed cut successively two metal threads separated by a measured space. Since 13 cm. distance between the threads gave a time of 1 σ, accurate time measurements were

easily, but may we add quite inconveniently, made. The relations found between duration and intensity of current for threshold excitation were essentially the same as those found by *Hoorweg* with t (duration) substituted for RC (capacity times resistance) in *Hoorweg's* formula.

In 1904, *Gildemeister* observed (47), independently of *Lapicque*, that only the beginning of any stimulating current is useful. He called this useful duration the *Nutzzeit* or serviceable time which corresponds to *Lapicque's temps utile*. *Lapicque* states that the *temps utile* is generally about ten times the chronaxie so that these two measures should not be confused.

Keith Lucas (68) also had been using measures of the minimal time necessary for excitation for analysis of complex excitable tissues coincident with the independent of the work of *Lapicque*.

By a series of careful experiments *Lapicque, Louis* and *Madame* (62, 63) in 1903–1907 demonstrated that the laws of *Weiss* and *Hoorweg* did not hold with mathematical exactness and were not applicable to very long times or very long intensities of current. Accepting as an approximation the law of *Weiss* represented by the formula $i=a/t \div b$ where t is the duration of current, i the minimal intensity for the duration t and a and b are two constants depending upon variations in experimental conditions, *Lapicque* introduced the concepts of *chronaxie* and *rheobase*, which have a definite experimental meaning. He divided the law of *Weiss* by b and gets $i/b=a/bt \div b/b$ and $i=b\ (a/bt \div 1)$. By replacing a/b by the value T the formula takes the form $i=b(T/t \div 1)$, then $i=2b$ when $t=T$. He then substituted rheobase for b and chronaxie for T and he has concepts with experimental value. The rheobase is the intensity of current necessary to obtain a threshold contraction with a prolonged continuous current. The chronaxie is the time of passage of current necessary to obtain a threshold contraction with an intensity double that of the rheobase.

Regardless of the theoretical validity of *Lapicque's* derivation of chronaxie, it has proved to be of experimental value in hundreds of important researches. Since the reason for the use of double the minimal intensity for reliable durational thresholds

has a more certain empirical than theoretical validity it may be best demonstrated by the following curve (Fig. 9), obtained in our researches by the use of the condenser method, of the relation between time and intensity for threshold contractions.

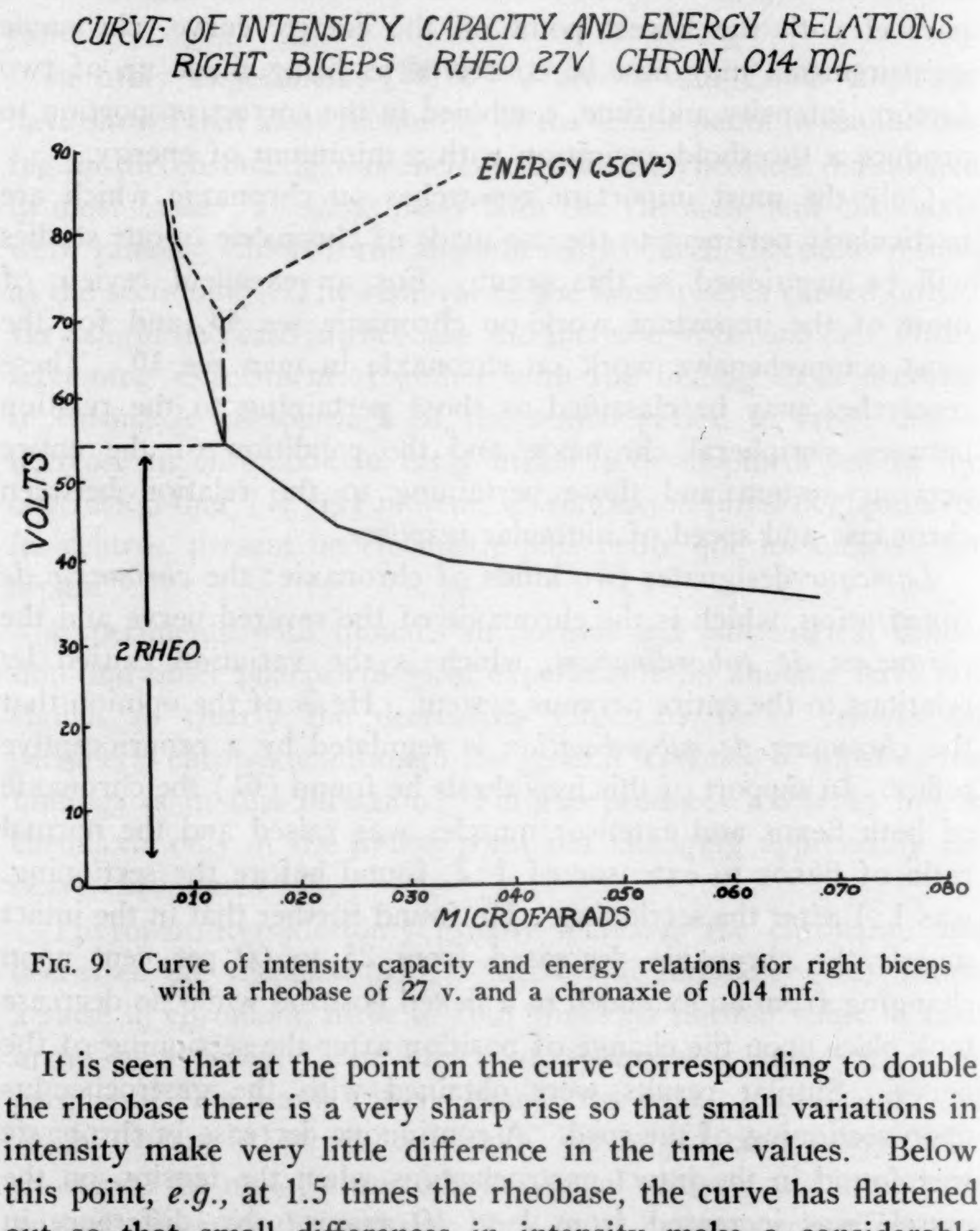


FIG. 9. Curve of intensity capacity and energy relations for right biceps with a rheobase of 27 v. and a chronaxie of .014 mf.

It is seen that at the point on the curve corresponding to double the rheobase there is a very sharp rise so that small variations in intensity make very little difference in the time values. Below this point, *e.g.,* at 1.5 times the rheobase, the curve has flattened out so that small differences in intensity make a considerable difference in the time threshold. Because of the difficulty in obtaining and maintaining a constant intensity of stimulation, it is very important that the intensity used for the determination of

temporal thresholds be above 1.5 times the rheobase to make unavoidable experimental errors in intensive determination of little consequence in the determination of an accurate temporal threshold.

Since the point on the intensive time curve at 2 rheobase is parallel with the lowest point on the energy curve, chronaxie measurements may best be conceived as being made up of two factors, intensity and time, combined in the correct proportion to produce a threshold excitation with a minimum of energy.

Only the most important researches on chronaxie which are particularly pertinent to the use made of chronaxie in our studies will be mentioned at this point. For an excellent review of most of the important work on chronaxie see 43, and for the most comprehensive work on chronaxie in man see 10. These researches may be classified as those pertaining to the relation between peripheral chronaxie and the condition of the entire nervous system and those pertaining to the relation between chronaxie and speed of muscular response.

Lapicque designates two kinds of chronaxie: the *chronaxie de constitution,* which is the chronaxie of the severed nerve and the *chronaxie de subordination,* which is the variation caused by relations to the entire nervous system. He is of the opinion that the *chronaxie de subordination* is regulated by a proprioceptive reflex. In support of this hypothesis he found (61) the chronaxie of both flexor and extensor muscles was raised and the normal ratio of flexor to extensor of 1:2, found before the sectioning, was 1:1 after the sectioning. He found further that in the intact muscle the chronaxie decreased from 25 to 60 per cent upon changing from an extended to a flexed position while no decrease took place upon the change of position after the sectioning of the nerve. Similar results were obtained with the gastrocnemius upon sectioning of the cord. A continuous decrease in chronaxie was found in the intact gastrocnemius when the tension on the muscle was increased from 1 to 10 grams. No difference in chronaxie could be observed with increased tension after sectioning of the cord.

In another report of an experiment on a dog (60) *Lapicque*

found that the sectioning of the cord caused a decrease in the extensor chronaxie and an increase in the flexor chronaxie so that the ratio becomes 1 : 1. Under ether anesthesia chronaxies which were .025 mf. for the extensors and .010 for the flexors became .012 mf. and .020 mf. respectively, tending to reverse the normal ratio.

In other experiments (58, 59) *Marcelle* and *Louis Lapicque* have shown that after sectioning of the sciatic nerve in the lumbar region the chronaxie was increased and the rheobase diminished in most cases. In some cases both the rheobase and chronaxie were raised. Chloroform anaesthesia produced the same results as the sectioning. The removal of the hemispheres caused only a very slight decrease in rheobase and increase in chronaxie. Other sectioning experiments together with the finding of a decrease in chronaxie at approach of the sexual period in frogs and a decrease in chronaxie in early infantile development led to the conclusion that " le nerf moteur, en connexion physiologique avec les centres, present un chronaxie plus petite que lorsqu'il en est sépare ".

Experiments with humans in normal and pathological condition and other pharmacological experiments on animals have not shown so clearly the decreasing effect of nerve centers on peripheral chronaxie although the general tendency of most of the findings is in this direction. Fatigue produces a rise in motor chronaxie only at the motor point not changing appreciably the nerve chronaxie (13).

Thyroparathyroidectomy greatly increases the chronaxie and decreases the rheobase (16). *Façon* and *Kreindler* (39) found a raise in chronaxie three to four times its normal value in man under anæsthesia. The effect of sympathetic innervation on peripheral chronaxie was shown by the experiments of *Weiss* (106) in which adrenalin prolonged and acetylcholin shortened the motor chronaxie in normal subjects and in patients with diseases of the anterior horn cells, but no such effect was obtained in patients with peripheral nerve lesions involving the sympathetic supply. Alcohol has been shown to raise the chronaxie of cortical centers (20) but the only consistent effect

observed in peripheral muscles is that of altering the ratio of flexor and extensor muscles.

Bourguinon has developed the concept of *reperkussion* to describe the effect of central disturbances upon peripheral chronaxie. In some cases of known central lesion he has found a rise in the cortical chronaxie of as much as 20 times the normal and a corresponding rise in the peripheral chronaxie of four to five times the normal (**14**).

In studies of post-encephalitic *Parkinsonism* three types of variations are observed: (1) an equalization of the chronaxie between the agonists and the antagonists at the motor point, (2) modification of the ratio between the chronaxies of flexors and extensors, either by a diminution of flexor chronaxie and an increase in extensor chronaxie, or by a diminution of the extensor chronaxie and an increase in the flexor chronaxie, (3) a heterochronism between the muscles and the nerves which is always due to an augmentation of the chronaxie of the muscle (**10, 70**).

Stein (**91**) found a general lowering and equalization of all motor chronaxies in strong rigor of the muscles of entire limbs of encephalitic patients as the general rule but found that pyramidal disturbances are not always associated with these results. He pointed out that *Bourguinon's* results were varied in regard to the effects of pyramidal lesions.

Bourguinon (**12**), in his most recent report of some of the results obtained on a great number of cases of both central and peripheral lesions together with results from experimental *reperkussion* in the rabbit, comes to the conclusion that nerve chronaxies are never affected to a very great degree by either central or peripheral disturbances but only the chronaxie of the motor point of the muscle is affected and usually the muscle chronaxie is raised in pyramidal lesions. He concluded that there must be two excitable substances, the " intra-muscular nervous fibers " and the " extra-muscular fibers ". Motor chronaxie varied not only with any change that takes place in the entire nervous system but with modifications of *milieu interieur* such as hyperthyroidism and variations in circulation. This finding tends to support the

findings of *Keith Lucas* and his collaborators on the two excitable substances in the "nerve muscle complex"' of different chronaxie values (**85**).

Early experiments of *Chauchard* (**19**), *Bourguinon* (**11**), and others seemed to indicate that the chronaxie of a given muscle was the same from its peripheral motor point along its entire path up the cord to its cortical localization. More recent experiments of *Chauchard* and *Kajiwari* (**18**), however, indicate that the normal ratio of 1 : 2 for the peripheral motor points of flexors and extensors does not hold in their cortical area of stimulation. In some cases, in fact, the ratio is found to be reversed.

Several lines of evidence have been brought forward in favor of the hypothesis that a long chronaxie corresponds to a slow velocity of conduction (**43**). Smooth muscles have a much larger chronaxie than do striated muscles. In the branches of the *His* bundle in the heart of a dog the speed of conduction is about three times longer than in the auricular tissue, which corresponds to a chronaxie three times as large as the chronaxie of auricular tissue. The thinner fibers in a nerve trunk have relatively lower velocities of conduction, as shown by *Gasser* and *Erlanger* (**37**, **38**) and they also have the longer chronaxies. Nerves classified with the vegetative nervous system have much longer chronaxies than have the nerves of the central system.

Even though it is very evident from the brief review of some of the experiments on chronaxie that there is much confusing and even conflicting evidence in regard to interpretations of chronaxie findings, it seems to the writer that the majority of the findings point to the following expectations from chronaxie measures of homologous paired muscles as related to basic neural asymmetry:

1. A low chronaxie in the right muscle of a homologous pair of muscles in definitely right handed subjects and a lower chronaxie in the left muscle of a homologous pair of muscles in left handed subjects if the activity of nervous centers tends to reduce the chronaxie of peripheral muscles in intact normal human beings. This same result would be expected on the basis of the relation between speed of conduction and chronaxie in correspondence with the findings of *Orton* and *Travis* (**81**) in regard to the precedence of action-currents in the forearms of right handed subjects during simultaneous voluntary flexion of the digits.

2. Variations in peripheral chronaxie associated with variations in activity of central nervous connections including disturbances of the flexor-extensor ratio in more severe cases of decrease in central control.

3. Every chronaxie measurement, dependent upon such a vast complex of physiological variables that indications of small differences due to conditions of neural asymmetry, might easily be masked by other more potent factors in the physiological moment at the time of measurement.

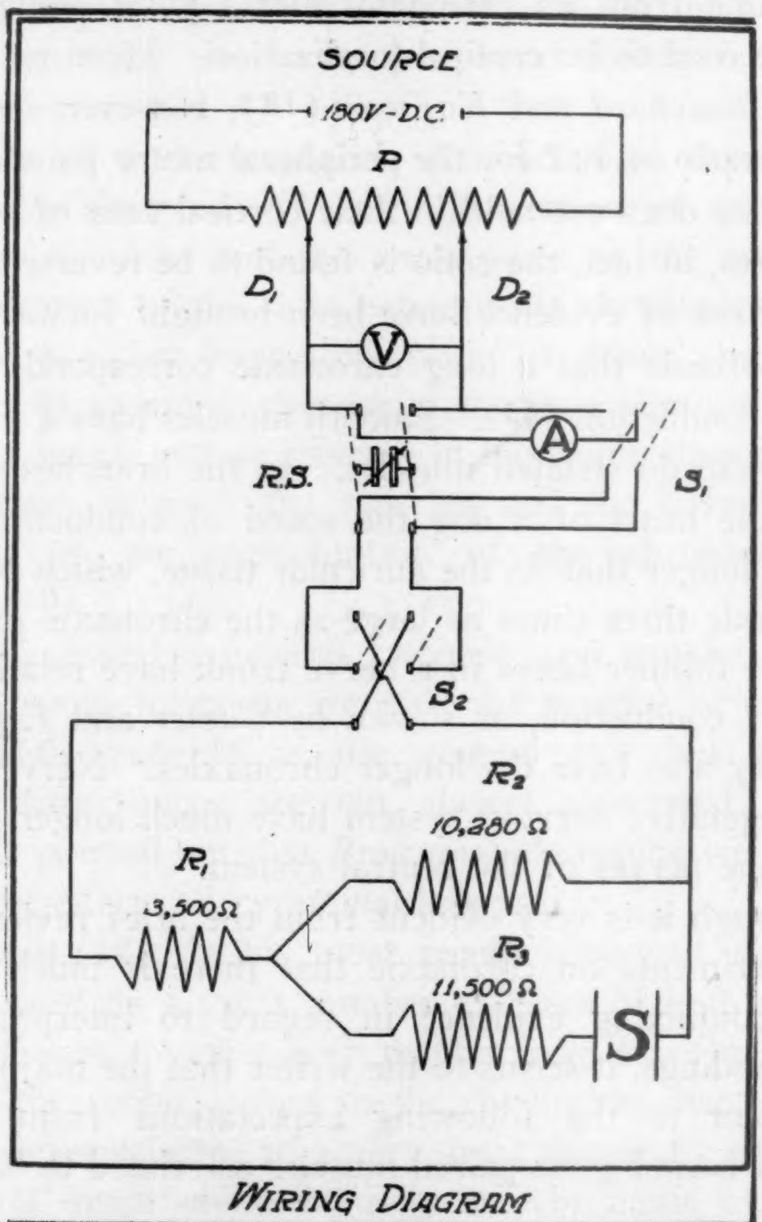


FIG. 10. Wiring diagram of chronaxie apparatus.

The apparatus used in our experiments was designed after the models of *Bourguinon* and *Stein.*. It consisted of a source of 180 v. D.C. current furnished by rectifying and stepping up the 110 A.C. source by means of a National B-eliminator type 3580. A capacity and induction free potentiometer was made up in two

sections, one for coarse adjustments (dial P_1 in Fig. 11) and the other for fine adjustments (dial P_2 in Fig. 11) from zero to maximum voltage. A voltmeter with a 200 V scale (V in

Fig. 11. Chronaxie apparatus. L=light for reflection from mirror on muscle. RS=rocker switch. E and E=electrodes which can be attached to the muscle. D_1, D_2, D_3, and D_4=dials of bank of condensers. P_1 and P_2=potentiometer dials. S_2=polarity reversing switch. V=voltmeter across the source.

Fig. 10) was placed in shunt across the two potentiometer contacts as shown in the wiring diagram. Direct connection was made between the two potentiometer contacts and one end of a double pole double throw rocker switch (RS in Figs. 10 and 11). The two central contacts of this switch were attached to a bank of condensers arranged in a condenser bridge form so that (by the manipulation of the dials D_1, D_2, D_3, and D_4 in Fig. 11) any

FIG. 12. Chronaxie apparatus under experimental conditions. *E* with left hand on rocker switch and right hand on dials of condenser bank—watching light on wall reflected from mirror (m) on muscle.

capacity from .001 to 12.000 mf. in .001 mf. units could be obtained. Condensers with capacities from .001 to .100 were of mica while those of the larger values were of paper. A careful check on the capacities of the dial values with the condensers intact was made periodically by balancing against a precision condenser of known capacity. A milliammeter was placed in series with a double pole single throw switch across the two end contacts of the rocker switch so that the circuit could be shorted directly through the milliammeter to the subject when checking

differences in body resistance of different subjects. In the discharge circuit was the reversing switch PS for changing the polarity to prevent excessive polarization and the shunt circuit in which was placed the subject S. Fixed carbon resistances were used for R_1 and R_2 while R_3, directly in series with the subject, was a variable carbon-pile resistor.

A copper chlorided sheet 15 by 7.5 cm. covered with canton flannel soaked in isotonic NaCl was used as the " ground " electrode. The effective electrodes were made of silver 16 mm. in diameter plated with AgCl by electrolyzing with a current of five ma. in a one per cent solution of NaCl for thirty minutes. They were then covered with several thicknesses of canton flannel and soaked in isotonic NaCl. These electrodes were first attached to a hard rubber handle as advised by *Lapicque* and *Bourguinon,* but owing to the impossibility of holding them in the some position on the muscle, the device illustrated in Figs. 10 and 11 was constructed.

The light L shown in Figs. 11 and 12 was an 8 v. concentrated filiament automobile globe mounted in a brass tube inserted in light socket of a desk lamp. A lens was placed at its focal distance from the filament of the light to cause the light from the filament to come out in parallel rays. The entire set-up, as is shown in Fig. 11, could be easily carried by one man and set up quickly in any ward where there was a light socket.

At the beginning of our studies the usual method of chronaxie determination was employed. It consisted essentially of the following steps:

1. The condenser dials were set at their maximum of 12 mf. This produced what may be considered physiologically an infinite duration of current for a human striated muscle.
2. The potentiometer was set at a voltage (known by previous experience) to be approximately 1.5 times the expected rheobase for the muscle in question.
3. The muscle was stimulated, by means of the rocker switch which charged the condensers and discharged into the circuit of the subject, around the region of the motor point until the point was found which produced the maximum contraction. The voltage was then decreased a little and the muscle again stimulated until the best motor point was obtained. This precaution was very important since only slight deviations from the motor point might have caused large deviations in chronaxie.
4. The voltage was then decreased until the intensity of current was just

strong enough to produce a perceptible contraction. The voltage at this point was the rheobase.

5. The potentiometer was adjusted so that there was double the rheobasic voltage at the source.

6. All the capacity was taken out of the bank of condensers except about the average threshold capacity for the muscle in question.

7. The capacity was then varied about and below the threshold in small units until the smallest capacity which will produce a perceptible contraction was reached.

8. The threshold capacity in microfarads times four gave the chronaxie in σ.

The condenser method of obtaining small units of time was used because of its simplicity of operation and construction in the form of our portable unit. The time of discharge of a condenser was obtained by the formula RC in which R is the resistance in the circuit of discharge and C is the capacity of the condenser. Since only a portion of this time of discharge was effective, the major portion of the time of discharge taking place at a potential below the rheobase, it was necessary to introduce a constant into this equation for chronaxie determination. *Lapicque* determined empirically the value of this constant by comparing the results of rectangular waves with the condenser discharge. *Monnier* (77) has shown exactly the same constant may be derived mathematically assuming that (1) the discharge of a condenser ceases to act on the physiological object when the intensity falls below the rheobase and (2) that the energy necessary to obtain a given physiological effect is the same for a rectangular wave as for a condenser discharge, the strength of the discharge limited by the first assumption. The formula for chronaxie then becomes: T (in sec.)=.375 RC. With the resistance in the discharge circuit constant at approximately 10,650 ohms, the formula for chronaxie becomes simply: T (in σ)=4 C (in mf.).

If the rheobase is found to be so high that doubling is impossible chronaxie may be obtained from the formula: T (in σ)=4. $\frac{C(v-b)}{b}$ in which C is the threshold capacity found at voltage v, the maximal voltage, and b is the rheobase.

The shunting of the discharge circuit together with the resistance of 15,000 ohms in series with the subject made changes in the subject's resistance during the experiment negligible insofar

as they effected the chronaxie. It was found by preliminary experiments that the differences between the body resistance of different subjects were not negligible so that it was necessary to introduce a variable resistance directly in series with the subject. With switch S_1 closed and the potentiometer voltage set at 28 v. this resistance might be adjusted until the current in the discharge circuit is 3 ma. This made the resistance of the discharge circuit constant for all subjects.

Preliminary experiments by chronaxie methods ordinarily employed brought out several serious difficulties in the use of this technique for the determinations of differences between homologous paired muscles. (1) The dependence upon direct observation of the muscle for the presence of a perceptible contraction was found to be highly unreliable as checked by the use of several *O*s for the same contraction. (2) By varying the time values around the threshold in an unsystematic manner, a range of values was obtained each one of which produced an observable contraction only in a certain percentage of the number of stimulations at this value so that the arbitrary selection of the chronaxie value was uncertain. (3) Variations in chronaxie of individual muscles on successive determinations were so great that the small differences found between homologous pairs was of questionable significance.

These difficulties in technique were attacked with the collaboration of *Theodore Perkins* of the University of Kansas. Difficulties in observation of contractions were partially overcome at first by the use of sensitive air tambours attached to a system of levers which amplified the movement of the muscle in contraction about 40 times. This method was soon abandoned and the parallel beams from a concentrated filament light were focussed on a small mirror placed on the muscle at the point of maximum depression. This light was reflected to the wall in a sharp line so that very slight contractions, considerably below the threshold of direct observation, were easily observed. The arrangement of this device in relation to the subject and *E* is shown in Fig. 12.

In a single chronaxie determination a range of time values was

obtained at the upper limit of which 98 to 100 per cent of the stimuli produced observable contractions while at the lower limit from 2 to 5 per cent of the stimuli produced observable contractions. It was found that the distribution of the number of responses per unit variation in time within this range conformed remarkably well to the analogous distributions found in measurements of psychophysical thresholds. The possibility of this relation was suggested by *Tiffin* who was doing intensive research in psychophysical measurements by the constant process.

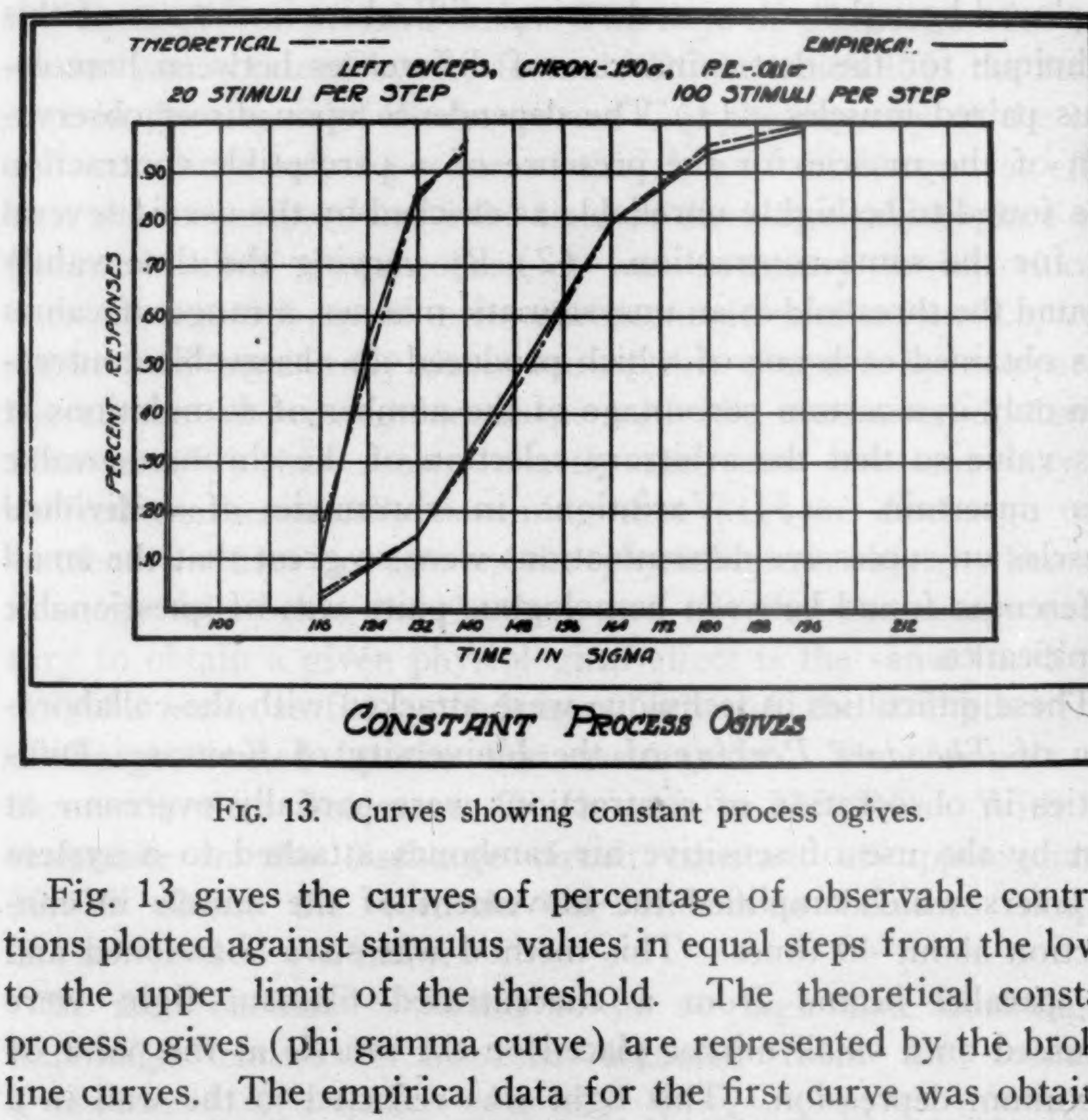


FIG. 13. Curves showing constant process ogives.

Fig. 13 gives the curves of percentage of observable contractions plotted against stimulus values in equal steps from the lower to the upper limit of the threshold. The theoretical constant process ogives (phi gamma curve) are represented by the broken line curves. The empirical data for the first curve was obtained by giving 20 stimuli on each of five equal steps, there being five stimuli to a step proceeding from the lower to the upper limit and then down until a sufficient number of stimuli had been given on each step. In like manner the second curve was obtained giving 100 stimuli to a step. The application of the chi squared

test of goodness of fit gave a very nearly perfect correspondence between theoretical expectations and empirical results.

Chronaxie values were, consequently, not absolute so that the problem resolved itself into the determination of the most probable value together with measures of the expected variability of this value. Since our data fall in line with psychometric theory we may use psychometric methods to this end (27). After the percentage of responses observed at each step was recorded the chronaxie could be determined by the formula for the constant process.

$$M = \frac{\Sigma Wx \Sigma Wx\gamma - \Sigma W\gamma \Sigma Wx^2}{\Sigma W \Sigma Wx\gamma - \Sigma Wx \Sigma W\gamma} \cdot (\text{c.i.}) + \text{guessed mean}$$

where c.i. = no. of units between each step and
x = deviations from the guessed mean
W = Urban's weights for the constant process
γ obtained from Urban's tables represents the deviation on the abscissa from the true mean which would give the observed proportions

$$h = \frac{\Sigma W \Sigma Wx\gamma - \Sigma Wx \Sigma W\gamma}{\Sigma W \Sigma Wx^2 - (\Sigma Wx)^2} \cdot (\text{c.i.})$$

The probable error may be determined from the formula

$$\text{P.E.} = \frac{.84535}{h\sqrt{2\,\Sigma\, n\, W\, p}}$$

where n = no. of stimuli on each step
W = Urban's weights (101)
p = per cent responses observed on each step.

The standard deviation may be determined from the formula

$$\text{S.D.} = \frac{1}{h\sqrt{2}}$$

One experiment will serve to illustrate the use of this method and some of its advantages. Electrodes were applied to both the right and left biceps so that determinations could be made on each muscle in rapid alternation merely by the shifting of poles on a double throw switch. One hundred stimuli were applied to first the right and then the left biceps (20 on each of five steps) alternately until 500 stimuli had been applied to each muscle. This series was completed in one hour and ten minutes. The chronaxie of the right biceps was found by the constant process to be .076 σ with a S.D. of .009 σ. The chronaxie of the left biceps was .150 σ with a S.D. of .017 σ. The obtained difference

of .074, being about four times its S.D. (.019), can certainly be considered statistically significant.

It is interesting to find that the phi gamma function applies to time thresholds of neuro-muscular excitability in the normal nerve-muscle complex[7] as well as to psychophysical thresholds, but the constant process as outlined above is too long to be practical for extensive application especially when other tests are included in the investigation. Nevertheless the writer is of the opinion that it is possibly the only method of obtaining accurate values for the chronaxie and its variability in a given muscle.

Another practical difficulty with the complete constant process is that, when using 100 stimuli on each step, the range shifts during an hour of experimentation. One can maintain a range, for example, of from .108 σ to .140 σ in some cases for only five or six minutes. This is just about sufficient time to give 20 stimuli on each of the five steps within that range. Since the curve of percentage response per unit-increase in stimulus gives a very satisfactory fit to the theoretical constant process ogive even with only 20 stimuli per step (Curve 1, Fig. 13) the constant process may be applied to these fluctuating thresholds. Some conception of the difference between this momentary threshold and the threshold obtained by successive stimulation over a period of more than an hour may be obtained by noting the difference in steepness of the two curves in Fig. 13. The first curve represents one of the momentary ranges near the lower end of the range of variation represented by the second curve. In determinations of successive chronaxies in a single muscle over a period of from three to six hours the highest value obtained would often be as much as double the lowest value. It is little wonder that *Bourguinon* came to the conclusion that variations in individual muscles is so great that one can not speak of individual differences.

The only hope left as to the possibility of obtaining reliable differences between homologous paired muscles was the possibility of some temporal parallelism in the direction of fluctuation, or the possibility that one muscle would maintain a chronaxie

[7] The phi gamma hypothesis does not hold, however, with some pathological cases.

greater than the other a sufficient majority of the time to obtain measurements of the differences. The following experiment was conducted to test these possibilities.

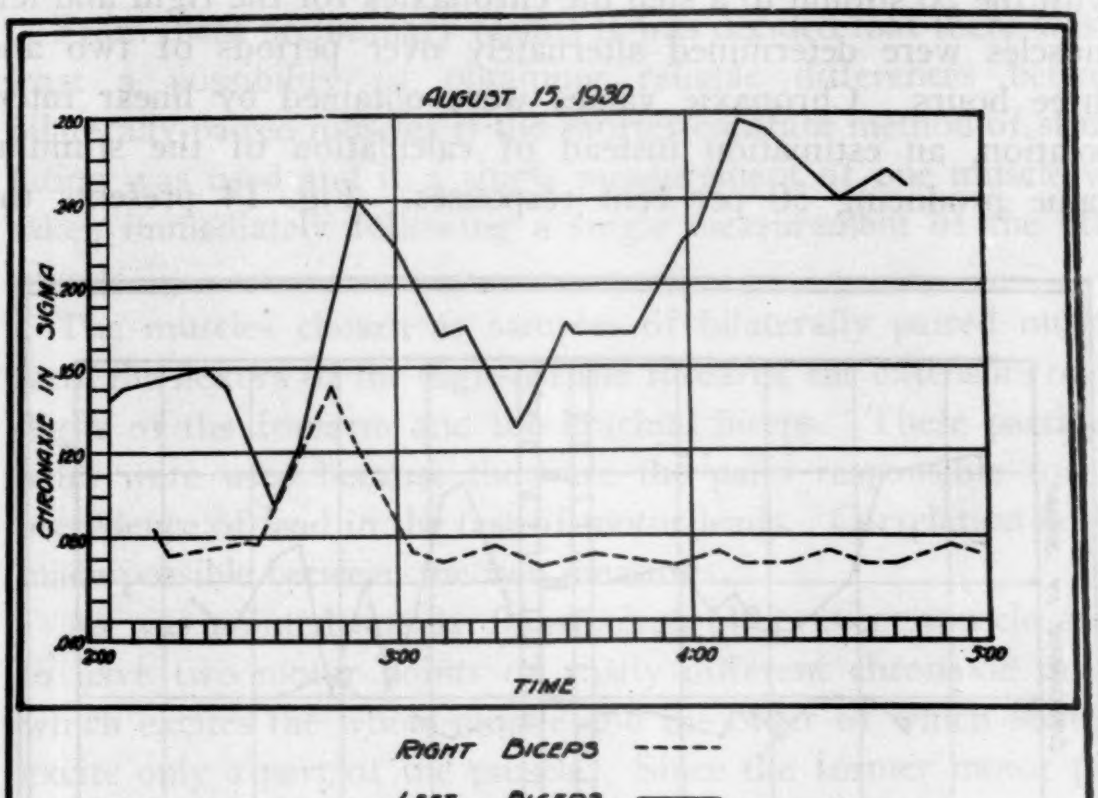


FIG. 14. Curves showing variations in chronaxie values of bilaterally paired muscles.

Electrodes were applied to the motor points of the right and left biceps so that the circuit would be quickly changed from one muscle to another. Using the constant method of stimulation with the 20 stimuli to a step the chronaxies for the right and left muscles were determined alternately over periods of two and three hours. Chronaxie values were obtained by linear interpolation, an estimation instead of calculation of the stimulus value producing 50 per cent responses. Fig. 14 presents the

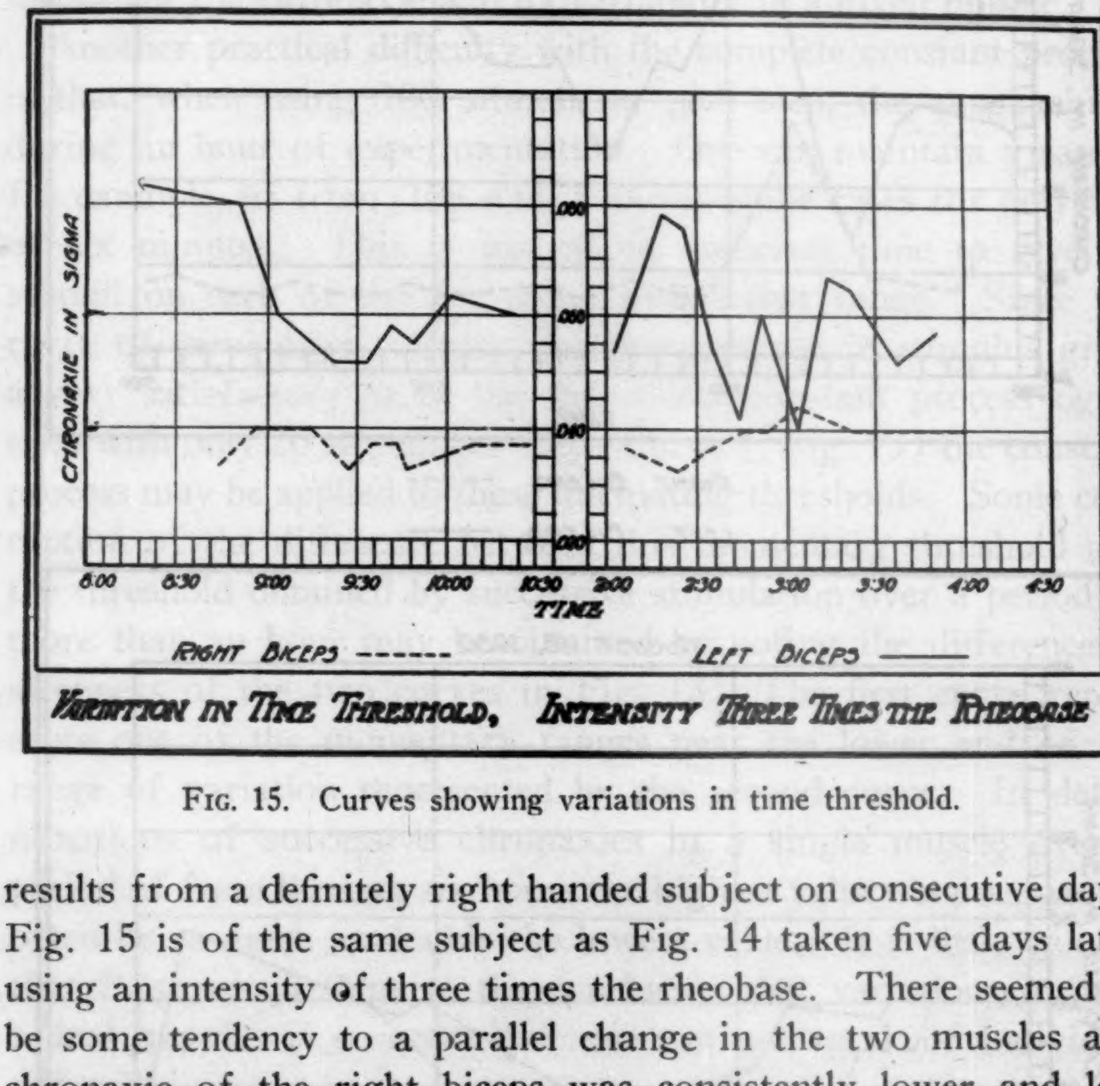


FIG. 15. Curves showing variations in time threshold.

results from a definitely right handed subject on consecutive days. Fig. 15 is of the same subject as Fig. 14 taken five days later using an intensity of three times the rheobase. There seemed to be some tendency to a parallel change in the two muscles and chronaxie of the right biceps was consistently lower and less variable than that of the left. Other curves essentially the same as those presented were obtained on the same subject on four consecutive days of experimentation with varying frequencies of stimulation, varying periods between measurements, and in one series using the flexors of the digits instead of the biceps. A shorter series of like measurements was made on three other right

handed subjects. Two of these subjects confirmed the results described above while the third showed several instances of shift in relation between the right and left muscles although the chronaxie on the right muscle was lower the majority of the time.

From these preliminary results it was decided that there was at least a possibility of obtaining reliable differences between bilaterally paired muscles if the shorter constant method of stimulation was used and if a single measurement of one muscle was taken immediately following a single measurement of the other muscle.

The muscles chosen as samples of bilaterally paired muscles were the flexors of the digits of the forearm, the extensors of the digits of the forearm and the brachial biceps. These particular pairs were used because they are the pairs responsible for the precedence of lead in the test of motor leads. Correlation is thus made possible between the two measures.

As was pointed out by *Bourguinon* (10), every muscle seems to have two motor points of vastly different chronaxie one of which excites the whole muscle and the other of which seems to excite only a part of the muscle. Since the former motor point is differentiated as being the one which gives the largest twitch with the lowest intensity of current, the attempt was made to use this point on all muscles. In the extensors of the forearms the superior motor point (distal) was always about double the chronaxie of the inferior point, the inferior point having about the same chronaxie as that of the flexors. Since no attempt was made to get data on extensor-flexor ratio in most of the normal subjects the particular group of extensor muscles used depended upon which motor point was the most easily found alike on the paired muscles. The superior point was used except in cases where a good motor point could not be found.

The normal subjects used were primarily selected from those in the RN, LN, and AN groups who seemed to show some consistency (predominantly right or left) in lead as indicated by the motor lead test. Nineteen of the group of stutterers were examined.

On the basis of expected lower chronaxie in the muscles of the

right arm for right handed subjects and a lower chronaxie in the muscles of the left arm in left handed subjects a particular muscle was termed right or left if it showed a significantly lower chronaxie than its pair.

Since most of the chronaxies were determined by linear interpolation instead of by the full constant process the significance of differences could not be determined for each measure on the basis of measures of variability. The P.E.'s of five of the constant process distributions showing the widest range were calculated for each muscle respectively. Since the P.E.'s calculated from these distributions would all be at least as large as any of the other distributions they were used for the derivation of a criterion of significance of difference which could be safely applied to all measures. In terms of a difference of three times its P.E. being considered statistically significant differences of .016 σ for the biceps, .020 σ for the flexors and .024 σ for the extensors were considered significant. By using these criteria of significance very few differences were considered significant where there was an overlapping of the two distributions. Since no adequate measure of variability was possible for the rheobase differences 10 per cent was arbitrarily considered as significant.

Tables XVI, XVII, XVIII, and XIX give the laterality of each of the bilaterally paired muscles which was found to be significantly lower in chronaxie and rheobase. Each subject in all of the four groups is represented, R designating the right muscle, L designating the left muscle, and O designating no significant difference between the two muscles.

All of these subjects were very definitely right handed in practically all of the habitual manual acts included in the handedness inventory. The chronaxie measures on the biceps of the RN group indicated 61 per cent (2.3 S.D.) more right laterality than left laterality and the same degree of left laterality as of ambilaterality. The rheobase measures ran fairly parallel to the chronaxie measures.

The chronaxie measures on the flexors of the digits in the RN group indicated 54 per cent (2.1 S.D.) more right than left laterality and a greater difference in the same direction in the

rheobase measures. There was 84 per cent (3.6 S.D.) more right laterality than ambilaterality while there was no significant difference between the amount of left laterality and ambilaterality as indicated by the chronaxie measures. In the extensor muscles of the RN group the chronaxie measures indicated 51 per cent (2.2 S.D.) more right than left laterality. The chronaxie measures also indicated 100 per cent more right laterality than ambilaterality.

TABLE XVI. *Right handed normal speakers; laterality of paired muscles on the basis of a significantly lower value in chronaxie and rheobase*

	Biceps		Flex. Dig.		Ext. Dig.	
Subjects	Chron.	Rheo.	Chron.	Rheo.	Chron.	Rheo.
1	O	L	R	O	R	O
2	R	O	L	R	L	R
3	R	O	R	O	R	R
4	L	R	L	O	L	O
5	O	L	L	O	L	L
6	R	R	R	O	R	R
7	R	L	O	R	R	R
8	R	L	R	R	R	R
9	L	O	L	R	R	L
10	R	R	R	R	L	L
11	O	R	O	L	R	R
12	R	R	R	R	R	O
13	R	R	R	R	R	O
14	R	R	R	R	R	O
15	L	R	L	O	L	O
16	R	R	R	R	R	O
17	L	L	R	O	L	L
18	O	L	R	L	R	R
			Per cent			
Right	.56	.50	.61	.50	.67	.39
Left	.22	.33	.28	.11	.33	.22
No. Diff.	.22	.70	.11	.39	.00	.39

The chronaxie measures on the biceps of the LN group indicated 89 per cent (3.6 S.D.) more left than right laterality, a slightly greater amount (1.3 S.D.) of left laterality than ambilaterality, and 84 per cent (2.4 S.D.) more ambilaterality than right laterality. These results differed from the same comparison on the RN group in that there seemed to be a greater relative degree of ambilaterality in the LN group. The rheobase measurements showed about the same general tendencies as the chronaxie measurements for this muscle although the differences were less significant.

The chronaxie measures on the flexors of the digits in the LN group indicated 62 per cent (2 S.D.) more left than right laterality, a slightly greater amount (1.1 S.D.) of left laterality than ambilaterality, and a slightly greater amount (1.5 S.D.) of ambilaterality than right laterality. There was no significant difference between the amount of right, left, and ambilateral indications from the rheobase measures.

TABLE XVII. *Left handed normal speakers; laterality of paired muscles on the basis of a significantly lower value in chronaxie and rheobase*

	Biceps		Flexors		Extensors	
Subjects	Chron.	Rheo.	Chron.	Rheo.	Chron.	Rheo.
1	L	L	L	L	L	O
2	L	L	R	R	R	R
3	L	O	O	R	R	O
4	L	O	L	O	R	O
5	R	R	L	L	L	L
6	L	L	R	R	R	O
7	O	L	L	L	L	R
8	L	L	L	O	R	O
9	L	O	R	L	L	L
10	L	L	O	L	L	O
11	O	L	L	R	R	O
12	L	R	L	L	L	R
13	O	R	O	O	O	R
14	O	R	O	O	R	L
15	O	L	O	R	R	O
16	O	R	L	O	O	O
	Per cent					
Right	.06	.31	.19	.31	.50	.25
Left	.56	.50	.50	.375	.375	.19
No Diff.	.38	.19	.31	.31	.125	.56

The chronaxie measures on the extensors of the digits in the LN group showed no significant difference (.7 S.D.) between the amount of right and left laterality, 75 per cent (2.5 S.D.) more right laterality than ambilaterality, and 67 per cent (1.7 S.D.) more left laterality than ambilaterality. The rheobasic measures also indicated about the same degree of right as left laterality but considerably more (2.1 S.D.) ambilaterality than either right or left laterality.

It seemed that the degree of left laterality in chronaxie measurements of the LN group decreased continuously from a significant amount in the more basic proximal musculature to even a slight tendency to right laterality in the more distal differentiated

musculature. This tendency was even more in evidence when individual cases were given consideration.

Subjects 3, 4, 7, 8, 9, 10, 11, and 16 were the only very definitely left handed subjects in this group as indicated by the inventory of present manual hand preferences. When these subjects alone were considered it was found that five of them had a lower chronaxie on the left biceps and the other three showed no significant difference between the right and left biceps, none of them having shown a lower chronaxie on the right biceps. On the flexor of the digits five subjects in this group also had a lower chronaxie on the left muscle, two subjects had no significant difference between the right and left muscles and one subject showed a lower chronaxie on the right muscle. On the extensors of the digits only three subjects in this group showed a lower chronaxie on the left muscle while four subjects showed a lower chronaxie on the right muscle and one subject showed no significant difference between the chronaxies on the right and left sides. What might have been considered the general laterality of neural organization in these subjects was reflected only in the measurements of the more basic musculature.

Subjects 2, 6, 14, and 15 wrote with the right hand but showed a left hand preference in a large number of other unimanual acts. Two of these subjects showed a left laterality of the biceps in both chronaxie and rheobase and a right laterality in both flexors and extensors of the digits. The other two subjects showed ambilaterality in both the biceps and flexors of the digits but a right laterality in the extensors. The more highly differentiated muscles seemed to reflect the superficial laterality imposed by the writing habit while the more basic muscles seemed to reflect the more general or basic nature of bilateral neural organization. This conclusion is supported by a like finding in the test of motor leads in which the basic laterality of the subjects was in evidence only on the biceps while the extensors showed a predominance of right leads in all subjects.

The chronaxie measures of the AN group showed no significant differences between the amount of right and left laterality in any of the musculatures although there was a tendency

(1 S.D.) towards left laterality in the biceps. This tendency decreased with the flexors while with the extensor muscles there was exactly the same amount of right as of left laterality. The rheobase values corresponded fairly well with the chronaxie values for the biceps and flexors but revealed the tendency to ambilaterality more in the extensor muscle.

TABLE XVIII. *Ambidextrous normal speakers; laterality of paired muscles on the basis of a significantly lower value in chronaxie and rheobase*

	Biceps		Flexors		Extensors	
Subjects	Chron.	Rheo.	Chron.	Rheo.	Chron.	Rheo.
1	O	O	O	O	L	R
2	L	L	R	L	R	O
3	L	O	L	R	L	O
4	R	L	R	L	L	R
5	R	L	R	O	R	O
6	O	O	R	R	R	O
7	L	L	R	R	R	O
8	L	R	L	O	L	O
9	L	R	L	L	L	L
10	O	R	L	O	L	O
11	R	O	O	O	O	O
12	O	L	O	R	R	O
13	O	O	O	O	O	O
14	O	L	L	L	R	R
15	R	O	R	R	R	R
16	L	O	O	O	L	L
17	L	R	O	R	R	L
18	R	L	O	L	O	O
19	L	O	O	R	L	L
	Per cent					
Right	.26	.21	.32	.37	.42	.21
Left	.42	.37	.47	.26	.42	.21
No Diff.	.31	.42	.21	.37	.16	.58

Subjects 6, 13, 14, 17, and 19 had histories of very pronounced left handedness when young and were shifted only partially and with difficulty. In the biceps chronaxie three of these subjects showed perfect ambilaterality and the other two showed left laterality. In the flexor of the digits chronaxie three of these subjects showed left laterality, one subject showed right laterality and the other ambilaterality. In the extensor muscle chronaxie three of the subjects in this group showed right laterality, one showed ambilaterality and the other left laterality. The tendencies to left laterality and ambilaterality are more pronounced in these shift cases in the proximal than in the distal musculature.

Chronaxie measures on the biceps of the S group indicated very little difference (1.2 S.D.) between the degrees of right and left laterality while there was 69 per cent (2.5 S.D.) more ambilaterality than left laterality. Rheobase measures indicated also a tendency to more ambilaterality than either right or left laterality.

TABLE XIX. *Stutterers; laterality of paired muscles on the basis of a significantly lower value in chronaxie and rheobase*

	Biceps		Flexors		Extensors	
Subjects	Chron.	Rheo.	Chron.	Rheo.	Chron.	Rheo.
1	R	O	O	R	R	L
2	L	O	R	L	L	O
3	R	O	L	O	R	L
4	O	L	O	R	O	R
5	O	R	O	R	L	O
6	O	O	O	R	O	L
7	R	O	R	L	R	O
8	O	L	O	L	L	O
9	R	L	L	L	L	R
10	R	R	O	O	L	R
11	O	O	L	L	O	O
12	L	O	O	R	L	O
13	R	L	O	L	L	L
14	O	L	L	L	L	R
15	O	L	L	L	O	R
16	O	R	O	L	O	O
17	O	R	O	R	R	L
18	O	O	O	O	O	O
19	L	R	L	R	R	R
	Per cent					
Right	.32	.26	.105	.37	.26	.315
Left	.16	.315	.315	.47	.42	.26
No Diff.	.52	.42	.58	.16	.32	.42

The chronaxie measures on the flexors of the digits of the S group indicated 66 per cent (1.5 S.D.) more left than right laterality, 82 per cent (3.5 S.D.) more ambilaterality than right laterality, and 46 per cent (1.7 S.D.) more ambilaterality than left laterality. Here the rheobasic indications did not parallel the chronaxie indications but showed less ambilaterality than either right or left laterality although there was no significant difference between the amount of right and left laterality. Both the chronaxie measures and the rheobase measures on the extensors of the digits in the S group indicated about the same degree of right, left, and ambilaterality.

TABLE XX. *Group percentages of right laterality in chronaxie and rheobase*

	RN	LN	AN	S
Biceps				
Chron.	.56	.06	.26	.32
Rheo.	.50	.31	.21	.26
Flex. dig.				
Chron.	.61	.19	.32	.105
Rheo.	.50	.31	.37	.37
Ext. dig.				
Chron.	.67	.50	.42	.26
Rheo.	.39	.25	.21	.315

TABLE XXI. *Group percentages of left laterality in chronaxie and rheobase*

	RN	LN	AN	S
Biceps				
Chron.	.22	.56	.42	.16
Rheo.	.33	.50	.37	.315
Flex. dig.				
Chron.	.28	.50	.47	.315
Rheo.	.11	.375	.26	.47
Ext. dig.				
Chron.	.33	.375	.42	.42
Rheo.	.22	.19	.21	.26

TABLE XXII. *Group percentages of ambilaterality in chronaxie and rheobase*

	RN	LN	AN	S
Biceps				
Chron.	.22	.38	.31	.52
Rheo.	.17	.19	.42	.42
Flex. dig.				
Chron.	.11	.31	.21	.58
Rheo.	.39	.31	.37	.16
Ext. dig.				
Chron.	.00	.125	.16	.32
Rheo.	.39	.56	.58	.42

A comparison of group percentages of right, left and ambilaterality from Tables XX to XXII indicates the following relationships:

Chronaxie Measures

1. The measures on the biceps indicated 89 per cent (3.8 S.D.) more *right* laterality in the RN group than in the LN group, 61 per cent (2.2 S.D.) more *left* laterality in the LN group than in the RN group, and gave a very slight indication (1 S.D.) of more ambilaterality in the LN than in the RN group. The S group had about the same degree of right laterality as did the AN group while both of these groups had more right laterality (1.9 S.D.) than the LN group and less right laterality (1.7 S.D.) than the RN group. The S group showed less left laterality than either the LN or AN groups (2.5 S.D. to 3.0 S.D.) and about the same left laterality as the RN group. The S group showed more ambilaterality than any of the other groups differing more in this respect from the RN group (2 S.D.) than from the LN and AN groups (.8 S.D. and 1.4 S.D.).

2. The measures on the flexors of the digits indicated 61 per cent (2.8 S.D.) more right laterality in the RN group than in the LN group, but the LN group had only a slightly greater amount (1.3 S.D.) of left laterality than had the RN group which was probably due to the fact that the LN group had a slightly greater amount (1.4 S.D.) of ambilaterality than had the RN group. The S group showed less right laterality than any of the other groups, the difference being significant with the RN group (3.8 S.D.) of possibly slight significance with the LN group. The four groups did not differ greatly in the percentage of left laterality there being only a suggestive indication (1.3 S.D.) that the LN and AN groups had a higher percentage of left laterality than had the RN and S groups. The S group had a higher percentage of ambilaterality than any of the other three groups, the difference being of greater significance with the RN group (3.4 S.D.) than with the AN group (2.4 S.D.) and of very little significance (1.6 S.D.) with the LN group.

3. The measures on the extensors of the digits indicated no significant differences between the RN, LN, and AN groups in percentage of right and left laterality while the LN group had 12.5 per cent ambilaterality and the AN group 16 per cent ambilaterality as compared to no ambilaterality on the part of the RN group. The S. group showed slightly less (1 S.D. to 2.7 S.D.) percentage of right laterality than the other three groups, the greatest difference having been with the RN group and the least difference having been with the AN group. There was no significant difference between the S group and the other three groups in the amount of left laterality but the S group seemed to have more ambilaterality than the RN group.

These results showed the same tendency in regard to the relation between proximal and distal musculature as was shown in the motor leads tests and in the other aspects of the chronaxie results. When the less differentiated more proximal musculature was used for indications of basic functional asymmetry, differences were found between the left handed and right handed subjects and the stutterers were classed either with the ambidextrous or left handed subjects but when the more differentiated distal musculature was used for such indications, the group differences either became of very slight significance or disappeared entirely. Asymmetry in general nervous organization may, therefore, be conceived in terms of a central unilateral gradient which is manifest in decreasing amounts and in more varied forms from the central to the peripheral aspects of the organism.

The group average values of chronaxie and rheobase, presented in Table XXIII, showed the same relations that have been described in the analysis of the data on chronaxie indications of laterality together with some additional findings:

(1) There was practically no difference between the average rheobase values for a given muscle on the right or left side or between these values for a given muscle in all of the four groups.

(2) The average chronaxie of the right biceps of the RN group was significantly smaller (2.8 S.D.) than the average chronaxie on the left biceps but there was no significant difference between the average chronaxie of the right and left flexors or of the right and left extensors in this group.

(3) The average chronaxie of the left biceps in the LN group was significantly smaller (3 S.D.) than the average chronaxie of the right biceps while there was no significant difference between the average chronaxie of the right and left extensors or right and left flexors.

(4) The AN group showed no significant differences between the average chronaxie of the right and left sides on any muscle.

(5) The S group also showed no significant differences between the average chronaxies of the right and left sides for any muscle.

(6) The S group differed from the groups of normal speakers in the ratio of chronaxie values between the three pairs of muscles. In the normal speakers there seemed to be a ratio of approximately 1 to 2 between the biceps and flexors and a like ratio between the flexors and extensors, the ratio between the biceps and extensors being about 1 to 4. In the S group there was a ratio of about 1 to 1.3 between the biceps and flexors, of about 1 to 1.6 between the flexors and extensors, and of about 1 to 2.3 between the biceps and extensors.

TABLE XXIII. *Group averages in chronaxie of bilaterally paired muscles*
(Chron. in σ, Rheo. in volts)

Group			Biceps Chron.	Biceps Rheo.	Flex. Dig. Chron.	Flex. Dig. Rheo.	Ext. Dig. Chron.	Ext. Dig. Rheo.
RN	R	M	.101	31	.245	38	.457	50
		S.D.	(.008)	(2)	(.022)	(2)	(.073)	(2)
	L	M	.127	31	.252	43	.510	50
		S.D.	(.005)	(3)	(.022)	(3)	(.079)	(3)
LN	R	M	.129	34	.180	43	.471	52
		S.D.	(.004)	(2)	(.020)	(2)	(.087)	(3)
	L	M	.099	33	.167	44	.467	53
		S.D.	(.009)	(2)	(.020)	(1)	(.093)	(3)
AN	R	M	.119	34	.191	41	.460	51
		S.D.	(.011)	(2)	(.017)	(1)	(.046)	(3)
	L	M	.112	34	.172	41	.423	50
		S.D.	(.007)	(2)	(.020)	(3)	(.046)	(3)
S	R	M	.105	34	.167	46	.256	56
		S.D.	(.007)	(2)	(.014)	(3)	(.34)	(3)
	L	M	.112	33	.136	44	.246	53
		S.D.	(.007)	(2)	(.020)	(1)	(.023)	(3)

The ratio between the extensors of the S group and the extensors of the normal speakers was about 1.9. The significance of this difference between stutterers and normal speakers is difficult to determine in the present state of chronaxie research. There might be some relation between this finding and the finding of a higher correspondence between number of right leads (on the leadometer test) in the flexors and extensors in stutterers than

in right handed normal speakers. There may be less differentiation from proximal to distal musculature in stutterers than in normal speakers.

On the basis of a lower chronaxie value of peripheral musculature indicative of more active neural centers our results indicated that when the measurement was taken on the biceps muscle a little over half of strictly right handed subjects showed by this measure the expected lower chronaxie on the right muscle. Only about 20 per cent of the right handed subjects showed a lower chronaxie on the left muscle. Our left handed group showed a little over half of the individuals with a lower chronaxie on the left side while only six per cent of this group showed a lower chronaxie on the right side. These results are quite significant in view of the many difficulties connected with obtaining these measures, making the probabilities of obtaining the wrong right or left indication very great. It is possible that with improvements in the control of the incidental variables influencing chronaxie measurements they would make a significant contribution to the diagnosis of unilaterality.

The opportunity was afforded to test the reliability of these differences between bilaterally paired muscles by reëxamination of several subjects after a lapse of from one to ten months. Of the five normal subjects tested four of them showed the same relative differences between the three paired muscles on the re-test although the absolute values were very different and the other one, who was a perfectly ambidextrous subject, showed a slight left tendency on one muscle on the first test while there were no significant differences between the right and left paired muscles on the re-test. This is entirely too small a number of cases to permit definite conclusions to be drawn but they suggest that, although the absolute values of chronaxie measurements are highly variable the relative values of bilaterally paired muscles remain about the same. At least a muscle on one side has a lower chronaxie than its pair a sufficient majority of the times so that the chance of obtaining an indication of this tendency in any single measurement is greater than the chance of obtaining the contrary indication.

Our results do not support the accepted assumption in clinical practice that the muscles of one side, to be normal, should have the same chronaxie as the muscles of the other side since a greater percentage of stutterers than normal speakers were found with bilaterally equal chronaxies. These results again demonstrate the relatively ambilateral neural organization of stutterers as compared to normal speakers but they differentiate the stutterers from the ambidextrous normal speaker only on the basis of absolute value of extensor chronaxie and not on the basis of degree of unilaterality. Since there is some indication from the chronaxie literature that the extensor chronaxie is reduced in the process of equalization of flexor and extensor chronaxies upon the decrease of cortical activity we might assume that our results indicate a general decrease in cortical control over peripheral processes effected bilaterally as the chief distinction between the stutterer and the ambidextrous normal speaker since these two types of subjects could not be differentiated (by the chronaxie measures or by several of the other measures in this study) on the basis of degree of unilaterality.

The chronaxie results have failed to present any evidence in support of the conclusion drawn from the motor leads test with regard to the greater difference between indications of central laterality and handedness on the part of the stutterers as compared to the normal speakers. If it is assumed that the biceps reflect the more basic laterality and the more distal muscles reflect the more superficial laterality, as was assumed with the motor leads test, the stutterers seem to be more perfectly ambilateral in basic laterality and more sinistral in superficial laterality according to chronaxie indications of laterality. This is contrary to the interpretation given the results of the motor leads test. However, both the results of the motor leads test and the chronaxie measures indicate a smaller degree of differentiation, both unilateral and central-peripheral, in the functional neural organization of the stutterers as compared to all groups of normal speakers which appears to be the most significant difference between the group of stutterers and the groups of normal speakers. The

relative homogeneity in bilateral or central-peripheral relations within the nervous system of the stutterers suggest either a lack of developmental maturity or a dis-differentiation produced by some pathological influence on nervous functioning.

VII. Inter-relation between measures. By the ordinary statistical procedures, it is practically impossible to represent the inter-relationships between all of the measures used in this study. Correlation coefficients based upon the normality of a given distribution of scores can not be used with our groups of selected cases. The percentage correspondence between the diagnosis of subjects as right, left, or ambidextrous on the different tests does not present a true indication of the inter-relations between the tests because the element of chance operates in different and, in some cases, indeterminate ways in the different tests. In spite of this methodological difficulty the attempt will be made to present some indication of the more significant relations.

The LN and RN groups were used for the study of most of the inter-relations between tests because if there was a definite relation between a left indication on one test, for example, and a like indication on another it would be shown more clearly in the definitely unilateral groups than in the ambilateral groups.

An estimate of the relation between tests will be made on the basis of the percentage of correspondence between diagnosis (right, left or ambilateral) on one test and a like diagnosis on the compared test. Corrections for the expected correspondence on the basis of purely chance elements operating in a given test will be made insofar as the chance expectancy can be determined.[8] The significance of differences in percentage between the per cent of correspondence expected by chance and that actually obtained will be used as an indication of the correlation between tests. Some of the more significant inter-relationships between the measures are as follows: (the LN and RN groups are used in the comparison unless other groups are mentioned).

[8] The chance of a correspondence in diagnosis between two tests is considered as the product of the influence of chance in one test and the influence of chance in the compared test. The influence of chance in a given test is not always easily determined but as close approximations as possible will be made.

Mirror Tracing, 1st trials and 2nd trials.

The RN and S groups showed about 50 per cent (4.2 S.D.) more than chance correspondence between the right or left diagnosis on the basis of the first two trials in order left-right and the right or left diagnosis in the second two trials in the order right-left. The LN and AN groups showed about 30 per cent (2.1 S.D.) more than chance correspondence between the above trials.

Unilateral Sighting and Visual Acuity.

There was about 31 per cent (2.8 S.D.) more than chance correspondence between indications of the best eye in tests of visual acuity and the eye preference in unilateral sighting.

Visual Acuity and Convergence Strength.

There was about 28 per cent (2.5 S.D.) more than chance[9] correspondence between the best eye in tests of visual acuity and the stronger eye in tests of convergence strength.

Visual Acuity and Convergence-Divergence Fixations Speed.

The RN group showed only a very slight indication of a positive relation (.7 S.D.) between visual acuity and speed of convergence-divergence fixations while the LN group showed 13 per cent (1.1 S.D.) less than chance correspondence between the best eye in tests of visual acuity and the more rapid eye in convergence-divergence fixations. The latter group showed 37 per cent (2.4 S.D.) more than chance correspondence between the best eye in tests of visual acuity and the slowest eye in convergence-divergence fixations. There seemed to be, in the LN group, a slight negative relationship between visual acuity and speed of eye movements in convergence-divergence fixations.

Visual Acuity and Dominant Eye in Pattern of Convergence-Divergence Fixations.

In the RN group there was 39 per cent (4.7 S.D.) more than chance correspondence between the dominant eye in convergence-divergence fixation patterns and the better eye in acuity while there was purely a chance relationship between the non-dominant eye in convergence-divergence fixation patterns and the better eye in acuity. In the LN group there was some indication that these relationships were reversed since there was purely chance correspondence between the dominant eye in convergence-divergence fixation patterns and the better eye in acuity while there was 25 per cent (1.70 S.D.) more than chance correspondence between the non-dominant eye in convergence-divergence pattern and the better eye in acuity.

Visual Acuity and Peripheral Dominance in the Phi Phenomenon.

The RN group showed no significant difference between chance correspondence and obtained correspondence in visual acuity and peripheral dominance in the phi phenomenon. The LN group showed 34 per cent (2.6 S.D.) more than chance correspondence between the better eye in visual acuity and the laterality of peripheral dominance in the phi phenomenon. The left handed subjects were influenced by visual acuity in peripheral dominance in perception of the phi phenomenon to a greater extent than were the right handed subjects.

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[9] It was assumed that there is an equal chance for right or left dominance in both speed and pattern of convergence-divergence fixations. There was probably less than this amount of chance since a few of the subjects gave no significant indications of either right or left dominance.

Visual Acuity and Central Dominance in the Phi Phenomenon.

The RN group showed 19 per cent (1.5 S.D.) more chance correspondence and the LN group showed 27 per cent (2.0 S.D.) more than chance correspondence between the better eye in acuity and central dominance in the perception of the phi phenomenon. This relationship was of interest since central dominance in this measure could not, by definition, exist with a dominance of the peripheral sense organ in perception.

Dominance in the Phi Phenomenon and Mirror Tracing Tests.

Neither the RN nor the LN groups showed any significant correspondence between the laterality of peripheral dominance in the phi phenomenon and laterality indicated by the Mirror Tracing Test. In the RN group there was 34 per cent (2.5 S.D.) more than chance correspondence between the laterality of central dominance in the phi phenomenon and the laterality indicated by the Mirror Tracing Test (first trials) although this correspondence was not significant in the LN group. The AN and S groups also showed no significant correspondence between either peripheral or central phi phenomena and the indications of laterality in the Mirror Tracing Test.

Central Phi Phenomena and Chronaxie Measurements.

The chance element in chronaxie measurements was difficult to determine but it was assumed for purposes of this comparison that there were equal chances of an individual giving indications of either right or left laterality in a given pair of muscles. This is placing the chance element at least as high as it really was. In the RN group there was 54 per cent (4 S.D.) more than chance correspondence between central dominance in the phi phenomena and chronaxie indications of laterality in the biceps muscles. This relationship decreased with the flexor muscle and still more with the extensor muscle until with the latter muscle there is only 37 per cent (2.7 S.D.) more than chance correspondence. These results might have been interpreted as indicating that chronaxie measurements reflect the laterality of the dominant gradient of activity in the neural centers responsible for central dominance in perception of the phi phenomena. The decrease in relationship from proximal to distal musculature supported the hypothesis presented in another connection, that the influence of a central unilateral gradient upon peripheral aspects of the organism decreased from proximal to distal neuro-muscular segments.

Motor Leads and Chronaxie Measures.

The influence of chance in both of these measures was very difficult to determine. A safe margin was allowed for the chance element in the chronaxie measures by assuming an equal chance for right or left indication since a few of the subjects gave an ambilateral indication. A 50 per cent allowance has also been made for the influence of chance in the motor leads test since a predominance in number of right over left leads was considered in this comparison.

The RN group showed 40 per cent (2.6 S.D.) more than chance correspondence between the laterality of lead on the extensors and the chronaxie indications of laterality on this muscle. The AN and LN groups showed about 28 per cent (1.8 S.D.) more than chance correspondence between these two measures on the extensor muscles. A significant correspondence was found also between these two measures on the flexor muscles but with this muscle the LN and AN groups showed the greater degree of correspondence. On the biceps of the RN and LN groups there was no significant correspondence between the laterality according to the predominance of motor leads and the laterality

according to chronaxie measurements. On the biceps of the AN group there was 41 per cent (2.5 S.D.) more than chance correspondence between laterality of motor leads and chronaxie indication of laterality. It seemed that in right and left handed normal speakers there was a certain correspondence between laterality of motor lead of the flexors and extensors and the laterality indicated by a lower chronaxie on the same musculature, while this relationship could not be definitely shown in the biceps muscle.

The fact that there was a varying amount of inter-relation between some of the different manifestations of neural asymmetry of function, a significant relation between such widely different processes as unilaterality in the field of perception and in the chronaxie measurement of relative excitability of bilaterally paired muscles, indicated that bilateral asymmetry of function was a general unilateral orientation of potentials within the nervous system affecting in varying degrees the peripheral manifestations of that asymmetry of function. The fact that there was but slight correspondence and in some cases no correspondence between the results of different tests used did not decrease the diagnostic value of these tests if they could be shown to be of diagnostic significance when related to the broad criteria of extremes in handedness. The fact that there was only a very limited inter-correlation between the different tests made each test the more valuable as participating in a battery of tests for the determination of *degrees* of unilaterality of function since unilaterality could not be conceived as an " either or " mechanistic sidedness but as an organismic unilateral variant.

VIII. Summary and conclusions. By means of an inventory of 76 unimanual acts groups of right handed, left handed, and ambidextrous normal speakers were selected from the extremes of a distribution of 332 cases examined for the predominance of manual preference. The diagnostic value of clinical tests for " native handedness " was critically examined on the basis of the degree of correspondence between the results of a specific test and the validating broad criteria of handedness. A group of " right handed " stutterers was examined for purposes of comparison between the three classes of normal speakers. Consideration was given the contribution of test results to the understanding of the bilateral neural organization of stutterers as well as of normal speakers. The following conclusions may be drawn

from the results of this study together with the results of other researches using the same tests:

A Critical Examination of Clinical Tests

1. *Unilateral sighting.* From 70 to 75 per cent of our strictly right handed normal subjects, 56 per cent of our ambidextrous normal subjects, from 45 to 50 per cent of our strictly left handed normal subjects, and 54 per cent of our " right handed " stutterers used the right visual line for sighting. This test can therefore be considered as of significance in individual clinical diagnosis only as it contributes to the general picture of an individual's sinistral or dextral tendencies obtained from a battery of tests. The results from this particular test together with like results on larger groups of cases serves to classify the stutterer with the ambidextrous and the left handed group of normal speakers on the basis of the degree of right laterality expressed in unilateral sighting.

2. *Simultaneous writing.* Seventy-five per cent of both our groups of right and left handed normal speakers, 64 per cent of our ambidextrous group of normal speakers, and 54 per cent of our group of stutterers as compared to 30 per cent of Travis's much larger group of stutterers presented the right orientation with both hands in simultaneous writing. The most common type of reversal for all subjects was the left (mirrored) orientation with the left hand. On the basis of the results of this study alone the simultaneous writing test can not be considered diagnostic for left handedness as there is no differentiation between sinistral and dextral groups of normal speakers. However, there is an indication that the stutterer presents a less definite unilaterality than does the right and left handed normal speaker and possibly even more ambilaterality than the ambidextrous normal speaker.

3. *Motor leads of bilaterally paired musculatures.* The average total amount (number of leads times extent of leads) of leads in " simultaneous " voluntary initiation of movement in the proximal musculature of the forearm (biceps) was found to be 33 per cent (2.7 S.D.) greater in the left than in the right

muscle in our group of right handed normal subjects and 28 per cent (2 S.D.) greater in the right than in the left muscle in our left handed group of subjects. These results were obtained under conditions similar to those of a reaction-time experiment. Under conditions of distraction the difference between the right and left musculatures becomes insignificant in the group of right handed normal speakers and is increased to a difference of 55 per cent (5.9 S.D.) more right than left leads in the group of left handed normal subjects. The ambidextrous group of subjects showed 37 per cent (3.5 S.D.) more left than right leads under reaction-time conditions similar to that shown by the right handed subjects but this difference persisted to a greater extent in the distracting conditions than it did with the right handed normals. The stutterers showed 26 per cent (2.1 S.D.) more right than left lead in the reaction-time conditions and 55 per cent (5.9 S.D.) more right than left lead in distracting conditions. This serves to classify the stutterers very definitely with the group of left handed normal speakers on the basis of their reactions in this experiment. The ambidextrous and right handed normal subjects showed more left lead in the reaction-time situation and no significant difference between amounts of right and left lead in the distracting conditions while the stutterers and left handed normal speakers showed more right than left lead in the reaction-time situation and a marked increase in amount of right over left lead in conditions of distraction.

When like results were taken on the distal musculature of the forearm (extensors of the digits) there was no longer any differentiation between the four groups of subjects, all of the groups having shown 22 to 28 per cent (over 2 S.D.) more right than left lead.

4. *Mirror drawing.* By determining the relative facility of the right and left hands in tracing a six pointed star in mirror vision it was found that there was no significant difference between the facility with the right and left hands in right handed subjects when the tracings were made in the order left-right-right-left. When the tracings were made in the order right-left-left-right the right handed subjects showed a signifi-

cantly greater facility with the left hand. The average time values for the four tracings were the same for the left handed subjects as it was for the right handed subjects when the order of trials for the former subjects was right-left-left-right showing that this latter order was comparable to the order left-right-right-left for the right handed subjects. This showed also that the mirror drawing test did not serve to distinguish between the right and left handed normal subjects. It was also found that the left handed subjects, both in the order of trials left-right-right-left and in the order right-left-left-right showed a tendency to less facility with the left handed than did the right handed subjects.

There was, however, a significantly greater percentage (3. S.D.) of stutterers than right or left handed normal speakers who showed greater facility with the left hand on the first trials in the order left-right. From the combined results of the studies of *Travis* and *Bryngelson* and of this study about half of the right handed normal speakers and about three-fourths of "right handed" stutterers should be expected to show greater facility with the left than the right hand under the same conditions. The former studies did not include left handed normal subjects so that it was assumed that this reaction on the part of the stutterers indicated a sinistral tendency but our results with left handed subjects indicate that it may be considered a dextral as well as (and perhaps better than) a sinistral tendency. It is necessary to make a further analysis of this differentiation between stutterers and normal speakers on the basis of their performance in initial trials in mirror tracing before the significance of the greater facility with the left hand on the part of stutterers is completely understood.

5. *Visual acuity.* There were no significant differences between the four groups of subjects on the basis of average acuity of the left as compared to the right eye. However, about 50 per cent (2 S.D.) more of the right than left handed subjects showed better acuity with the right than with the left eye.

Stutterers were distinguished from the groups of normal speakers in that they showed less difference between monocular and binocular acuity. The two eyes seemed to function more in

an additive manner in the binocular acuity of normal speakers than they did in stutterers.

6. *Convergence strength.* Fifty-four per cent of the group of right handed normal speakers, 27 per cent of the group of left handed normal speakers, and 23 per cent of the group of ambidextrous normal speakers were found to have the right eye dominant in strength of convergence. The difference of 27 per cent (2.5 S.D.) between right and left handed normals indicated that this test might contribute to a battery of tests for the detection of tendencies to general unilaterality. The stutterers were again classed with the ambidextrous and left handed groups of normal speakers since they had even more (20 per cent) left dominance than the left handed group itself. No significant difference was found between the group of ambidextrous normal speakers, the group of left handed normal speakers and the group of stutterers on the basis of the percentage with a dominance of the right eye, all of these groups presenting less right eyed dominance than the right handed normal subjects.

7. *Lead eye in binocular convergence and divergence fixations.* Photographic records of the movements of the two eyes in binocular convergence and divergence fixation adjustments were taken and evidences of asymmetry in the speed and pattern of movement were recorded. No difference was found between the stutterers, ambidextrous normals, left handed normals and right handed normals in the relative speed of convergent adjustment of the two eyes. However, it was found that the average speed of movement of the right eye in the left handed group of subjects was 23 per cent (2 S.D.) faster than the left eye. The stutterers showed this same tendency to a lesser degree while no significant difference could be observed between the speed of movement of the two eyes in the ambidextrous and right handed groups of normal speakers.

Asymmetry of function between the two eyes was very evident in the study of the binocular patterns of fixation adjustment. One eye moving towards the line of its next fixation would pull the other eye in a horizontal direction before the recessive eye would diverge or converge in the next fixation adjustment.

When there was a distinct evidence of this dominance of one eye over the other, the pattern was termed as either right or left dominance, while the term asymmetrical was applied to the patterns which presented no evidence of a dominant eye in the movement. The average per cent occurrence of these three types of fixation patterns in the four groups of subjects were tabulated.

In the convergent fixation patterns no very significant differences were observed between the four groups with the possible exception of a greater percentage (1.6 to 1.8 S.D.) of left patterns in the stutterers and left handed normal speakers as compared to the ambidextrous and right handed normal speakers.

In the divergent fixation patterns no significant difference was shown in the percentage occurrence of symmetrical patterns but the left handed group had 75 per cent (3.3 S.D.) and the stutterers 59.5 per cent (2 S.D.) more right than left lead patterns as compared to an equal percentage of right and left patterns for ambidextrous and right handed normal speakers. The same tendency to a predominance of right leads on the part of the left handed normal speakers and the stutterers as was observed in the motor leads tests with the biceps was present in divergence fixation patterns which suggests some basic general neural organization responsible for both phenomena. The lack of differentiation and the tendency to a predominance of right leads by all groups of subjects in the convergence fixations suggests that the convergent adjustment of the eyes is analogous to the reactions of the more highly differentiated musculature since a like result was obtained from the extensor motor leads.

Fourteen per cent of the divergent lead patterns presented by the stutterers seemed to alternate between right and left dominance in fixation adjustment while a negligible amount of this type of pattern was observed in the normal speakers. This suggests a tendency to an alternation in the peripheral expression of unilaterality on the part of some stutterers.

8. *Peripheral and central dominance in the perception of the phi phenomenon.* Upon alternation of a near and far point of light in a dark room when one of these lights was fixated, normal subjects perceived movement between the point fixated and one

of the homonymous or heteronymous doublings even though equal stimulation was present for movement to both of the doublings. Certain combinations of movements gave evidence of a right or left dominance of the eye (peripheral dominance) and an ambilaterality of the direct cortical connections while certain other combinations of movements gave evidence of a dominance of the right or left hemispheres (central dominance) and an ambilaterality of the eyes. It was found that 48 per cent of the group of right handed subjects indicated a right central dominance in perception while no right central dominance was shown in the group of stutterers and left handed normal speakers. The left handed group was characterized by more left central and left peripheral dominance and more central ambilaterality than was the right handed group. The stutterers corresponded to the left handed subjects in the amount of left peripheral dominance but had much more central ambilaterality than any of the normal speaking groups. The ambidextrous subjects were characterized by a relatively large amount of central ambilaterality, equal amounts of right and left central dominance and more right than left peripheral dominance.

This test gives promise of contributing a great deal to the diagnosis of both the central and peripheral aspects of tendencies to unilaterality.

9. *The relative excitability of bilaterally paired muscles.* Fifty-six to 67 per cent of the group of right handed normal speakers were shown to have lower chronaxies on the right than on the left pair of the biceps, flexors of the digits, and the extensors of the digits. Only 22 to 33 per cent of this group showed a lower chronaxie on the left pair. Thirty-eight to 50 per cent of the left handed group of normal speakers showed a lower chronaxie on the left of these paired muscles while only six per cent of this group had a lower chronaxie on the right biceps. Fifty per cent of this group showed a lower chronaxie on the left biceps. The average amount of difference between right and left paired muscles in the four groups seemed to decrease from proximal to distal musculature. The ambidextrous group of normal speakers and the stutterers were quite comparable relative to the other

groups of normal speakers but they differed in that the stutterers showed even more evidence of ambilaterality than the ambidextrous normal speakers while the latter group showed more evidence of left laterality than did the stutterers. The stutterers differed from all of the normal speakers in that with the normal speakers there was an average ratio of 1 to 2 between the biceps and the flexors of the digits, a ratio of from 1 to 2 between the flexors and extensors of the digits and a ratio of 1 to 4 between the biceps and extensors. In the stutterers there was found an average ratio of about 1 : 2 between the biceps and extensors, very little difference having been found between the biceps and the flexors. The average value of chronaxie on the extensors for the stutterers was found to be about one-half that found on the same muscles with the normal subjects. Interpretatively the chronaxie measurements characterize the group of stutterers as having less unilateral and central-peripheral differentiation in the functional organization of the nervous system as a whole.

More than chance correspondence was found between the diagnosis on some tests and the diagnosis on others. There was quite a marked relation found between such varied manifestations of unilaterality as dominance in the perception of movement in the phi phenomenon and relative excitability of bilaterally paired muscles at their motor points. Unilateral asymmetry of function may, therefore, be thought of as having for its basis or core a central orientational gradient, a differential of bilateral excitability, manifest to a certain degree in the more centrally determined peripheral processes, its influence decreasing as the peripheral fields of activity function more and more under the dominance of sub-gradients which are relatively independent of the general central gradient.

Single clear cut measures of laterality in nervous organization were not found in this study and they will never be found because the nature of functional asymmetry in bilateral nervous systems does not permit any such mechanistic reactions. Most of the tests of laterality critically examined and all of the new methods of approach introduced have shown sufficient diagnostic value to warrant their inclusion in a battery of tests for the determination

of tendencies toward certain types and degrees of laterality of function. Selection on the basis of handedness yielded individuals who presented definite group tendencies although there was always considerable variability between individuals within the group. In fact a strictly unilateral individual in all of the tests, including handedness, was a "lucky find". This serves to emphasize further the importance of using the pooled results (properly weighted) from a comprehensive battery of tests for the detection of the degree of laterality possessed by a given individual. Neural asymmetry must be considered both qualitatively and quantitatively as a functional variant.

It has been shown that the majority of clinical and laboratory tests serve to classify the stutterers quite definitely with the ambidextrous or left handed groups of normal speakers. These results support the dominance theory of stuttering insofar as they demonstrate the ambilateral or even sinistral nature of the bilateral neural organization of "right handed" stutterers. However, questions arise as to why the ambilateral normals do not stutter and as to why the few definitely right handed normal speakers expressing left laterality or ambilaterality in the majority of clinical and laboratory tests do not present any observable neural disturbance. Also we can not disregard the fact that a few of the stutterers presented more dextrality, when the pooled results of all tests are considered, than many of the ambidextrous normal speakers. On the basis of handedness as well as on the basis of clinical and laboratory tests of laterality the only means of differentiating a few of the stutterers from many of the normal speakers was the fact that in one case there was speech difficulty and in the other case there was normal speech. Certainly the results of this study do not indicate any simple causal relation between ambilaterality and stuttering as a broad all-inclusive generalization but the writer is convinced that a relative lack of differentiation especially with respect to unilaterality is an outstanding characteristic of the bilateral neural organization of stutterers. Further research on ambilateral normal speaking subjects as well as on the bilateral neural organization of cases with various types of nervous disorders

would throw more light on the function of ambilaterality in the etiology of stuttering.[10]

The results of this study point, however, to a possible means of explaining the normal speech of ambidextrous subjects in the light of the dominance theory of stuttering. Some tests differentiated between stutterers and all the normal speaking subjects, other tests showed that stutterers who possessed the same degree of right handedness as the ambidextrous normals exhibited more left unilaterality than the left handed group of normal speakers themselves. The test of central dominance in perception showed practically 100 per cent ambilaterality on the part of the stutterers. *Travis* has emphasized the concept of dominance as a " physiologic variant ". He states that a certain " margin " of dominance is necessary for effective speech. It is possible that these differences found between the stutterers and ambidextrous and left handed normal speakers are just enough to account for their difference in speech.

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[10] *Sherlock, Smedley, Lattes,* and others (**82**) have shown that there is a predominance of ambidexterity in the feebleminded and psychopathic constitutions which suggests that the ambidexterity found in most stutterers may be a basic predisposing condition which operates with other factors to produce the speech disorder.

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Appendix

Date........

HANDEDNESS INDEX

Name............... Age....... Sex....... Race....... Nationality.......

Are you right handed or left handed *now?*
Were you ever changed from left to right handedness?
Did you ever stutter? At what age? For how long?
Did you ever have the right arm or hand injured for any length of time?
For how long? At what age?
In using tools with long handles, the hands may be used in one of two ways:

A. Right hand near outer end of handle, left hand nearer the "business end" of the instrument—such as hoe, rake, etc.

B. Leht hand near outer end of handle, right hand nearer the "business end" of the instrument.

If in using the following tools, you almost always use your hands as in "A", draw a circle around "A".
If you almost always use your hands as in "B", draw a circle around "B". If you have no particular choice, draw a circle around "X".

1. Hoe	A B X	4. Shovel	A B X	7. Axe	A B X
2. Rake	A B X	5. Broom	A B X	8. Ball bat	A B X
3. Pitchfork	A B X	6. Spade	A B X	9. Golf club	A B X

10. In which direction do you ordinarily sweep: (1) Toward the right, (2) Toward the left, (3) No particular choice.
11. From which shoulder do you ordinarily swing a baseball bat: (1) Right, (2) Left, (3) No particular choice.

In doing the following acts, one hand does all or almost all of the work. If you almost always use the right hand, draw a circle around "R" If you almost always use the left hand, draw a circle around "L". If you have no particular choice, or if you use both hands (as, for example, shaving one side of your face with one hand, and the other side with the other hand), draw a circle around "X" Answer only for those acts which you have actually done.

1. Which hand drives billiard cue?	R L X
2. Which hand swings tennis racket?	R L X
3. Which hand throws a ball?	R L X
4. With which foot do you kick?	R L X

5. Which foot steps on a spade? R L X
6. Which hand does most in shuffling cards? R L X
7. Which hand deals the cards? R L X
8. Which hand works lever in filling your pen? R L X
9. Which hand turns the pages as you read? R L X
10. Which hand puts the letter in the envelope? R L X
11. Which hand puts the stamp on the envelope? R L X
12. Which hand tears open envelope? R L X
13. Which eye stays open when you aim a gun? R L X
14. Against which shoulder do you hold butt of gun? R L X
15. Which hand holds knife when you whittle? R L X
16. Which hand cuts with the knife in eating? R L X
17. Which hand holds the fork in eating? R L X
18. Which hand uses the salt shaker? R L X
19. (You hold a dish in one hand and wash or wipe it with the other.) Which hand washes the dish? R L X
20. Which hand wipes the dish? R L X
21. Which hand combs your hair? R L X
22. Which hand strops your razor? R L X
23. Which hand shaves your face? R L X
24. Which hand uses the powder puff? R L X
25. Which hand uses the tooth brush? R L X
26. Which hand winds your watch? R L X
27. Which hand scratches matches? R L X
28. Which hand holds your cigarette? R L X
29. Which hand uses the dust cloth? R L X
30. Which hand uses the needle in sewing? R L X
31. Which hand holds the thread in threading the needle? R L X
32. Which hand uses the scissors? R L X
33. When you wash your hands, which hand rubs the soap on the other? R L X
34. Which hand wraps the tie around when you tie your tie? R L X
35. Which hand would you use for lifting and carrying a cup level full of water? R L X
36. Which hand uses a saw? R L X
37. Which hand uses a hammer? R L X
38. Which hand uses a screw driver? R L X
39. Which hand uses wrenches? R L X
40. Which hand cranks a car? R L X
41. Which hand uses a key in a lock? R L X
42. Which hand turns nuts on bolts? R L X
43. Which hand handles the money which you pay for something? R L X
44. Which side do you sleep on? R L X
45. Which hand holds a paper cup for drinking? R L X
46. In jumping which foot gives the last push? R L X
47. Which hand goes in coat sleeve first? R L X
48. Under which arm do you usually carry books? R L X
49. Which hand turns a door knob? R L X
50. Which hand holds the receiver when telephoning? R L X
51. Which hand usually pulls out a drawer? R L X
52. Which hand hangs up your hat? R L X
53. Which hand stirs when mixing things? R L X
54. Which hand picks up right shoe when dressing? R L X
55. Which hand picks up left shoe when dressing? R L X

56. Which shoe do you take off first? R L X
57. Which shoe is put on first? R L X
58. Which stocking do you put on first? R L X
59. Which stocking do you take off first? R L X
60. Which glove is put on first? R L X
61. Which hand turns key when locking a door? R L X
62. Which hand reaches to pick up small object on floor in front of you? R L X
63. Which hand writes letters? R L X
64. Which hand draws pictures? R L X
65. Which hand does figuring? R L X
66. Which hand erases on paper? R L X
67. Which hand does the most manipulating when tying shoe string? R L X
68. Which hand leads in reaching to a high shelf? R L X
69. Which hand uses the can opener? R L X
70. Which hand turns egg beater? R L X
71. Which hand turns on water tap? R L X
72. Which hand takes mail out of box? R L X
73. Which hand pulls corks from bottles? R L X
74. Which hand supports you in rising from sitting position on floor? R L X
75. When standing with both feet together which foot goes forward first to catch yourself when you start to fall? R L X
76. Which ear do you turn towards a sound that is hard to hear? R L X

SOME COMMON FACTORS IN READING AND SPEECH DISABILITIES

by

GEORGE A. KELLY

I. Historical. The deep-seated and diffuse nature of the stutterer's defect has been emphasized by *Travis* (18). He has discovered numerous motor disturbances which accompany the activities of the stutterer but which are apparently unrelated to his speech. The explanation offered is that in the stutterer there is a tendency toward decentralized neural control resulting primarily from a lack of inherent bias for cerebral dominance or from lesions which reduce the ascendency of the higher motor centers. The result of this decentralized control is dysintegration of the nervous system, manifest in the case of stuttering in speech. The present study is an investigation of this and other factors which may be common to reading and speech disabilities.

Travis (19) and *Fossler* (6) have shown that the breathing of the stutterer during overt speech is dysintegrated from the standpoint of effectively producing normal speech. *Murray* (12), following these workers, has shown that similar dysintegrations occur in the breathing of stutterers during silent reading and reasoning. He has also pointed out the tendency toward a silent reading disability among stutterers.

Orton (13) reported that about 2 per cent of the school population have reading defects of the " word-blindness " type. He attributed this type of manifest defect to a difficulty in the building of associations between the visual and auditory spheres at the third functional level, the lowest level on which cerebral dominance plays any significant part. The natural inconsistency between visual and auditory stimuli is normally eradicated at this level, but, due to a lack of inherent bias toward cerebral dominance or to lesions, is in this type of reading defect the cause

of "congenital word blindness" (*strephosymbolia*). On this associational level the memorial images of the two visual cortices are mirrored counterparts of each other; thus a lack of dominance of one cortex over the other confuses the visual memory images and prevents normal imagery.

It is generally maintained that *Wernicke's* (auditory speech) center is directly involved in the production of overt speech. Cases have been recorded of bilateral lesion of this area producing loss of hearing and loss of speech, the motor centers being unaffected. This is called *Wernicke's* sensory aphasia. *Mott* (11) reports a clear-cut case of this sort. This direct connection with overt speech is not evident to the same extent in the case of the visual cortices of the occipital lobe. While lesions of the visual centers have been frequently observed they are not known to be entirely responsible for the loss of overt speech.

Bartley and *Perkins* (1) in comparing action currents obtained from the different areas of the dog's brain under varying circumstances found that the activity tended to be focalized in not less than two of the following areas, auditory, visual, motor. At one time the activity might be focalized in the auditory and visual areas with comparative quiescence in the motor area; at another time the activity might be focalized in the auditory and motor areas with comparative quiescence in the visual area; at another time the activity might be focalized in the visual and motor areas with comparative quiescence in the auditory area. Never was activity focalized in one area only.

Bluemel (3) at one time expressed the thesis that "the stammerer's difficulty is transient auditory amnesia". At that time he emphasized the contention that the stammerer was an "audito-moteur" type and his stammering was due to a loss of the memorial image of the sound which should follow that on which he stammers. More recently, however, he has expanded his conception of this transitory phenomenon. His recent thesis is that the stammerer is confronted with a discontinuity in the whole of his consciousness.

Ranschburg (14) attributed reading defects among children to lack of development of the carotid arteries with corresponding

reduction of the oxygen supply. *Starr* (16) reported low vital capacity and insufficient ventilation in stutterers. He has also found a high carbon-dioxide content and a low calcium concentration associated with stutterers. For certain types of stutterers (psychopathic) he has found low hydrogen ion concentrations; for others (normals) he reports extremely high hydrogen ion concentrations.

Studies of imaginal habits, mostly based upon introspection technique, have had perennial revivals since *Galton* (7) made his classic study of " types ". A review of the literature concerning these studies would be a dissertation in itself. One study of particular significance in the present connection is that reported by *Golla* and *Antonovitch* (9). A box plethysmograph, said by the authors to be unusually sensitive, was used in connection with a smoked drum kymograph for the recording of the subjects' breathing over a long period of time. Of 67 cases whose rest breathing was recorded over a considerable period of time, 34 were classed as " regular " breathers, 33 of which were " visual " types, and one was an " auditory " type. Of the 32 " irregular " breathers 28 were " auditory " types and 4 were " visual " types (1 case rejected). When given a problem to solve which required the use of visual imagery 25 of the 30 " irregular " breathers breathed regularly and the remaining five abandoned attempts to solve the problem. The breathing of the " regular " breathers remained unchanged during the solution of the problem. Such a striking conclusion as this appears to be, if verified, would have far-reaching significance in psychology and education. In the present investigation a check was made upon this finding and, as will be shown later, showed it not to be without partial substantiation.

Most of the experimental work with breathing curves, exclusive of studies of speech production, has attempted to link respiratory rhythm with changes of attention or with emotional states. *Skaggs* (15) reported shallow and more rapid breathing during silent reasoning and somewhat deeper, though rapid, breathing during emotional states. One of the first studies in the field was made in *Wundt's* laboratory by *Zoneff* and *Meumann* (20) and

revealed changes in respiratory rhythm with fluctuations of attention.

Probably one of the most significant investigations from the standpoint of the present study is that recently reported by *Bills* (2). In studying the decrements of work curves for homogeneous serial tasks he has observed certain periodicities in production efficiency which occur in rhythmic succession at the rate of about three a minute. The periods of efficiency were separated by periods of blocking when the tasks were performed slowly and imperfectly. Furthermore, the moments of maximum efficiency tended to be separated by just half a phase-length from the movements of minimum efficiency, thus indicating a truly cyclical phenomenon.

At about the same time *Knight* (10) observed periodicities in the occurrence of errors made by sixth grade children in solving multiplication problems involving several places in the multiplier. Errors occurred most frequently at the end of the problem and least frequently at the beginning. The rhythm of efficiency and inefficiency tended to adjust itself to changes in the tasks, that is, efficiency was partly restored at the beginning of each new problem. A finding of this nature is of primary importance in the field of educational method.

In 1927 *Farnsworth, Seashore,* and *Tinker* (5) published the results of a study which showed as high a correlation as +.53 between certain serial reaction times and Army Alpha intelligence scores. The correlation was considerably lower between serial reaction times and scores made on those intelligence tests which placed less emphasis upon the speed factor. The correlation of simple reaction times with intelligence scores was insignificant. *Gaskill* (8) reported a relationship between simple reaction times and the phase of breathing, the shortest reaction times occurring when the stimulus was given during the period between the phases of breathing, that is, when breathing movements were momentarily suspended.

II. Method. The first hypothesis taken into consideration by the present investigation was that those individuals who are defective in silent reading would exhibit dysintegrations in breath-

ing during silent reading similar to those of the stutterers during silent reading. Accordingly six groups of *O*s were chosen from the men of the 1930–31 freshman class of the University of Iowa. They were chosen on the basis of the entrance tests given to all freshmen who enter the University and on the basis of scores on the Iowa Silent Reading Comprehension Tests which were administered to nearly all freshmen as a part of a survey made by the Department of Speech. The groups were selected in the following manner: in one group were eight *O*s whose percentile ranks in the Iowa Silent Reading Comprehension Test were not only low, but considerably lower than their percentile ranks in the General Qualifying Examination, a test highly correlated with intelligence tests. In another group were eight *O*s matched with these on the basis of percentile ranks in the General Qualifying Examination but whose percentile ranks in the reading test were approximately the same as their ranks in the General Qualifying Examination. In another group were eight *O*s matched with the *O*s in the other two groups on the basis of percentile ranks in the General Qualifying Examination but whose percentile ranks on the reading test were relatively high. Similarly, there were four (it being impossible to match one score) *O*s whose percentile ranks in the reading test were high but whose percentile ranks in the General Qualifying Examination were higher, five matched on the basis of the percentile ranks in the General Qualifying Examination but with reading ranks approximately equivalent, and five matched on the basis of the percentile ranks in the General Qualifying Examination but with reading ranks relatively high.

The *O*s were called into the laboratory singly. Each *O* was seated in a chair facing a table on which were placed the materials which he used during the experiment. His breathing was recorded by means of two Boulitte pneumographs, one placed over the thorax at the level of the armpits and the other over the diaphragm about one inch inferior to the xiphoid process. The record was made with black Skrip ink on white paper with a Renshaw polygraph. The pulse from the left carotid artery was recorded similarly by means of a very sensitive tambour. A

Boulitte laryngeograph was used to record laryngeal movements simultaneously with the pulse and breathing movements. The polygraph was placed behind *O*. *E* sat at the right and slightly back of him.

The experimental series consisted of the following items, many of which are identical with those used by *Murray* (12) in his study of the breathing of stutterers during silent reading.

1. A period of adjustment for *O* during which he conversed freely with *E* and became accustomed to the hum of the polygraph.
2. A five-minute period of rest-breathing during whch *O* sat without moving or speaking while listening to the ticking of a Jacquet chronometer. He was instructed not to think about anything too intently and to bring his attention to the ticking if he found any other subject absorbing his interest.
3. Two minutes' silent reading of fairly difficult prose.
4. Answering in writing multiple-choice questions, visually presented, over the material he had just read.
5. Two minutes' silent reading of poetry.
6. Questions.
7. Two minutes' silent reading of light prose.
8. Questions.
9. One minute rest.
10. Solving and writing the answers to problems in mental arithmetic auditorially presented by the experimenter.
11. Visualizing the face of a clock. In this part of the experiment *O* was given a series of problems such as this: "Suppose it were twenty-three minutes past seven; what time would it be if the positions of the two hands of the clock were interchanged? Write your answer."
12. Silent reasoning. *O* was presented with a proposition such as this: "A falsehood is justifiable if to one's knowledge it will save the reputation of a friend." He was then told to make a decision as to the truth or falsity of the statement and to formulate three reasons for his answer. After *O* had indicated that his answer and reasons were ready he was asked to dictate them into an Ediphone. Five of these propositions were presented.
13. Memorizing from a visual stimulus. *O* was given a typewritten selection of an abstract nature and told that he would be given five minutes to memorize it.
14. Solving *Golla's* "visual imagery" problem. The exact procedure was as follows: *E* said, "Now imagine a number of blocks like the ones you used to play with when you were a child. Imagine you have built of them a cube, three blocks on a side; that is, a perfect cube, three blocks high, three blocks long and three blocks wide. Now imagine that you have painted it red all over and taken it apart. How many of the little blocks will have three sides red,—how many will have two sides red,—how many will have one side red? Lift your hand when you have the right answer. The cube was three blocks on a side."
15. Memorizing from auditory stimulus. *E* repeated four times a short selection similar to the one memorized from visual stimulus.
16. Visual aphasia test. In this test the presentations were made by means of a band of white paper stretched between the drums of a small kymograph. For the length of the band a black line appeared. Alternately above and below

this line appeared pairs of digits about 8 mm. high. A cardboard shield containing a window 22 mm. wide was placed around one of the kymograph drums so that when the kymograph was set in motion the pairs of digits were exposed successively. Following each pair of digits above the line appeared a pair of digits below the line, one of which had appeared in the previous pair and one of which was unlike either of the digits in the preceding pair. *O* was asked to pick out and write down the unrepeated digit in each pair of digits appearing below the line. Forty-five presentations were made at about 2 sec. intervals. A short practice period preceded the test.

17. Auditory aphasia test. In this test the presentations were made by means of an Ediphone record. Each presentation consisted of a three-place number spoken as follows: "Three hundred and twenty-nine!" *O* was asked to write the number with the positions of the first two digits interchanged, that is, in the above illustration he would write, "*2 3 9*". Forty presentations were made at 3 sec. intervals.

During the whole experiment, which usually consumed from an hour and a half to two hours, the polygraph was kept running and a continuous record of breathing, pulse, and laryngeal movements was made.

As criteria of breathing irregularity *Murray* (12) used the coefficients of variation of the following four variables: (a) duration of expiration, (b) duration of inspiration, (c) amplitude of expiration, (d) amplitude of inspiration. This involved making four measurements of each breathing curve and if carried out in the present study would have entailed measuring with a millimeter scale some 600,000 curves. Accordingly another method was devised, although for the breathing curves during silent reading individual measurements were made and coefficients of variation computed. Durations of expiration and of inspiration during the five minutes of rest breathing were measured, the means and standard deviations computed, and the normal range of values found, assuming a normal distribution to extend three standard deviations on either side of the mean. Thus a value of each of the two variables, duration of inspiration and duration of expiration, was found, values below which would fall outside the normal probable distribution. Likewise another value was found, values above which would fall outside the normal probable distribution. Thus with rest breathing as a standard, irregularity of breathing during the different tasks of the series could quickly be observed. Three measures of breathing irregularity were used, (a) the number of inspirations whose durations fell outside the

normal distribution of inspiration durations for rest breathing, divided by the time in seconds; (b) the number of expirations whose durations fell outside the normal distribution of expiration durations for rest breathing, divided by the time in seconds; (c) defining any expiration or inspiration whose duration was *greater* than the normal duration in rest breathing as a " block ", the total duration of all blocks in seconds divided by the total time in seconds. Measure " c " might be designated as the ratio of blocking time to total time.

III. Data and discussion: breathing irregularities of reading disability cases. By none of the three criteria of breathing irregularity was any consistent relation between breathing dysintegration and reading disability found, either with or without intelligence taken into consideration. Coefficients of variation based on individual measurements of each curve also showed no consistent difference between the groups of cases. The findings with respect to the hypothesis that reading defectives would show breathing irregularities during silent reading as do stutterers were essentially negative. They were consistent, however, with the findings reported elsewhere in this study.

General relation of reading and speech defects. The next question to be answered was whether or not there was any relation between speech and reading defects. *Murray* (12) reports that " stutterers appear to be approximately one grade below normal in rate of reading. The disparity is emphasized further at least one-half grade when their reading achievement is considered in relation to their true intelligence." The question remaining to be answered was whether or not the converse is true; are reading defectives defective speakers? It is to be remembered in this connection that stuttering is only a very specialized kind of speech disability while in the present connection no distinction between kinds of reading disability has been made.

Analysis of the speech of reading disability cases. In the present investigation an analysis was made of the speech of the 31 *O*s who made records under item 12 in the procedure described above. Five different criteria of speaking ability were used;

(a) the number of words spoken a second under the conditions of the experiment; (b) counting each hesitation of one second or less at a place where the thought content did not require a pause as a block of one second, the ratio of hesitation or blocking time to total time of speaking; (c) the ratio of repeated vowel sounds, excluding completed words, to the total number of words spoken; (d) the ratio of repeated words to the total number of words spoken; (e) the ratio of slurred words to the total number of words spoken. Slurred words were defined as those indistinctly spoken, either because of too short a phonation time or omission of one or more syllables.

The results of this analysis are shown in Table I. It is evident from this table that there is quite a definite relation between silent reading ability and speaking ability with intelligence held constant. Especially in the rate of speaking is the relationship brought out. These averages were computed on the basis of about 200 spoken words for each individual.

Analysis of silent reading scores on general speech disability cases. As a further check on the coincidence of reading and speech defects an analysis was made of the data obtained by the Department of Speech at the University of Iowa in its general survey of speech abilities among the members of the 1930–1931 freshman class. During the first semester of the year each freshman was given a general effectiveness rating on his speech by a committee chosen from the staff of the Department. For the 101, approximately the lowest decile, who were indicated as being defective speakers the mean percentile rank on the Iowa Silent Reading Test was 44.8, or very nearly at the median. Since general intelligence was operative both in determining the speech rating and the reading test rank it can scarcely be maintained on the basis of this finding alone that any other factor was responsible for the slightly low reading average.

By subtracting the percentile rank of each freshman on the reading test from his percentile rank on the General Qualifying Examination a measure of the discrepancy between the two could be obtained. For these freshmen rated as speech defectives (the same group described in the previous paragraph) the mean of

TABLE I. *Analysis of speech records in relation to silent reading and intelligence*

	No. of cases	Words per sec.	Block time: total time	Repeated vowels: total words	Repeated words: total words	Slurred words: total words
Reading ability and intelligence both relatively *low;* groups matched in intelligence						
Reading ability relatively lower...............	7	1.66	.46	.23	.06	.05
Reading ability relatively same................	7	1.94	.34	.06	.03	.05
Reading ability relatively higher..............	7	2.24	.36	.04	.01	.04
Reading ability and intelligence both relatively *high;* groups matched in intelligence						
Reading ability relatively lower...............	3	1.97	.44	.13	.06	.12
Reading ability relatively same................	4	2.20	.18	.03	.02	.04
Reading ability relatively higher..............	3	2.63	.30	.10	.04	.04

these percentile differences was only +1.1, indicating quite definitely that here there was no relation between speech and reading disability other than perhaps a low general intelligence. At this point it became apparent that if there were a relationship between reading disability and speech disability it must be of a particular rather than of a general nature.

Analysis of the relation of different aspects of the speech survey to silent reading disability. In rating each freshman's general effectiveness in speech the committee in charge of the survey scored on a scale of 1 to 10 each individual's ability in each of the following aspects of speech: articulation, voice, organization of materials, and symbolic formulation and expression. The intercorrelations between these scores and the raw scores on the silent reading tests are shown in Table II. From this table it can be seen that except for "halo" effects between scores on certain of the aspects of the speech rating the general interrelationship is insignificant. Coefficients were computed on the basis of random samples of 250 cases.

TABLE II. *Intercorrelations between aspects of the speech ratings and scores of the Iowa Silent Reading Test*

	Reading	Articulation	Voice	Speech organization	Symbolic formulation and expression
Reading		.080	.035	.090	.110
Articulation			.338	.219	.300
Voice				.260	.230
Speech organization					.549
Symbolic formulation and expression					

Analysis of the relation of different aspects of the silent reading test to speech disability. Since organization of materials was taken into consideration in rating each freshman's general effectiveness in speech it was thought that inability to organize might comprise a common element in speech and reading defects. For the 113 freshmen rated as deficient in speech organization the mean percentile rank in sentence organization as measured by the Iowa Silent Reading Comprehension Test was 46.36, or nearly at the median. Similarly, for the same group the mean percentile rank in paragraph organization as measured by the Iowa Silent Reading Comprehension Test was 46.77, again nearly at the

median. Apparently there is little relation between speech organization and sentence or paragraph organization during silent reading.

Relation between speech comprehension and silent reading comprehension. If general intelligence or general ability to comprehend language represented the only common element in speech and reading ability one would expect to find scores in silent reading comprehension and speech comprehension very highly correlated. Such, however, was not found to be the case. In connection with the same survey of speech abilities in the freshman class as was mentioned above, the *Travis-Barnes* Speech Comprehension Test was given. In giving this test the tester reads aloud a selection, after which the testee selects from four printed selections the one which he believes to be identical with the one read. Fifty selections are read in the entire test and the testee's score is the number which he is able correctly to identify on the printed page.

A coefficient of correlation of $+.575 \pm .030$ was obtained between this test and the Iowa Silent Reading Comprehension Test. This coefficient is far below that which would be expected if intelligence or general ability to comprehend language were the only factor involved. Scores on an auditory acuity test made in the general speech survey revealed no consistency with the scores on the *Travis-Barnes* Speech Comprehension Test. Thus it becomes evident that some factor other than general intelligence or even general language comprehension is operative in one or the other or both of these tests.

Relation of speech rhythm defects to silent reading disability. One aspect of the speech survey did appear to be definitely related to silent reading disability. For the 67 cases which were diagnosed as being defective in the rhythm of speech the mean percentile ranking on the General Qualifying Examination was 45.25 and the mean percentile ranking on the Iowa Silent Reading Test was 40.87, a discrepancy of 4.39. In this connection it should be borne in mind that silent reading comprehension is a very considerable element in any written examination and that therefore the above numerical difference is probably too small.

This finding checks with the analysis made of the records of the 31 cases whose speech was recorded on the Ediphone. All the measures used in that analysis were essentially measures of speech rhythm (see Table I). Thus on the basis of two studies defective speech rhythm was found to be related to reading disability. This pointed toward a common element in speech and reading defects which is essentially transient in nature.

Relation of silent reading disability to cerebral dominance as manifest in ambidextrality and sinistrality. For a further explanation of this essentially transient element the present investigation followed the lead of *Orton* (13) who emphasized the importance of " word blindness " or *strephosymbolia* in reading disability. It is true that *Orton* limited this defect to about 2 per cent of the school population, but it is conceivable that the defect is present to some extent in everyone. With *strephosymbolia* and stuttering (essentially a defect in speech rhythm), both being attributable to lack of cerebral dominance, it became a matter of prime importance to study the reading disabilities of those whose cerebral dominance was somewhat doubtful, that is, left handed and ambidextrous individuals.

Of 28 individuals who reported left handedness or ambidexterity in the speech survey 22 or 79 per cent had a lower percentile ranking in silent reading comprehension than in the General Qualifying Examination. The mean percentile ranking for this group on the Iowa Silent Reading Comprehension Test was 41.0 and the mean percentile ranking on the General Qualifying Examination was 47.6, a discrepancy of 6.6 percentiles. Again it should be pointed out that any silent reading disability would tend to influence unfavorably scores on the General Qualifying Examination.

In the speech survey 22 individuals reported having been changed from the left to the right hand at some time in their lives. Silent reading ranks were available for only 16 of these individuals; however, for this small group the mean reading percentile was 43.7 and the mean qualifying percentile was 47.9. It is interesting to note in passing that four of these individuals were stutterers.

Relation of transient sensory aphasia to silent reading disabilities. It is evident from the foregoing paragraphs that although there is a common element, essentially transient in nature, in reading and speech rhythm defect, there is still some discrepancy and the presence of one type of defect in an individual does not insure the presence of the other type of defect. An analysis of the two tests for transient aphasia will throw some light on this discrepancy. Table III shows the results. From

TABLE III. *Percentages of errors in the transient aphasia tests according to groups selected on the basis of the discrepancy between silent reading percentile ranks and percentile ranks in intelligence as measured on the Iowa General Qualifying Examination*

Groups:					
Intelligence low			Intelligence high		
Reading lower	Reading same	Reading higher	Reading lower	Reading same	Reading higher
Transient Visual Aphasia Test					
20.0% (7 cases)	11.9% (7 cases)	5.9% (7 cases)	1.0% (3 cases)	3.7% (5 cases)	2.7% (3 cases)
Transient Auditory Aphasia Test					
42.2% (7 cases)	26.2% (7 cases)	28.2% (7 cases)	15.0% (3 cases)	17.5% (5 cases)	21.8% (3 cases)

this table it can be seen that the percentage of errors made on the visual aphasia test, described under item 16 in the experimental series, is a fair measure of the silent reading ability with the intelligence held constant. The auditory aphasia test, described under item 17 in the experimental series, does not appear to be as closely related to silent reading ability.

Relation of transient sensory aphasia to defective speech rhythm. After examining the results shown in Table III the question arose whether or not the auditory test might be more closely related to speech rhythm defects. In order to test this hypothesis a much longer auditory aphasia test and a much longer visual aphasia test were constructed. The nature of the tests and the methods of presentation were retained but the number of presentations was increased to 133 in the auditory test and to 197 in the visual test. Time intervals between presentations remained unchanged in each case.

For the experiment 12 stutterers and an equivalent number of normal speakers were matched on the basis of age and advancement in school. All the individuals were either undergraduate or graduate students in the university. Table IV shows the

TABLE IV. *Stutterers and normals compared on basis of percentage of errors made on aphasia tests*

Normals			Stutterers		
O	Auditory aphasia test in %	Visual aphasia test in %	*O*	Auditory aphasia test in %	Visual aphasia test in %
Cr	.75	0	Ba	28.80	7.61
Ha	7.51	7.61	Be	61.60	34.50
Ke	.75	3.55	Fr	68.40	11.16
Ly	0	0	Cr	54.90	19.30
Ma.	36.80	9.14	Ne	67.60	3.04
Na	5.26	1.52	He	19.53	10.64
Pa	17.30	3.05	Ja	7.50	13.20
Pr	28.60	8.01	Jo	6.76	10.15
Ti	21.80	0	Ma	100.00	100.00
Wa	6.01	1.52	Sc	24.80	8.10
Wh	3.76	0	Sw	43.60	17.76
Wi	6.76	1.01	Va	42.10	12.70
Means:	11.28	2.95		43.80	20.68

results of this experiment. The differences are striking; here both visual aphasia and auditory aphasia tests appear to be closely related to stuttering. It can be seen, however, that those individuals who made a high percentage of errors on one test did not necessarily make a high percentage of errors on the other.

Preliminary generalizations. At this point it is possible to generalize from the foregoing results to some extent. In the first place the connection of reading disability to defective speech rhythm independent of general intelligence indicates a common element of a transient nature. In the second place the connection of reading disability to lack of cerebral dominance indicates the presence in reading disability cases of the same sort of neurological condition as that involved in stuttering. In the third place the more particular connection of transient aphasia in the visual test to reading disability and the more particular connection of transient aphasia in the auditory test to stuttering indicates a certain amount of differentiation between the sensory fields involved in this neurological condition. It would appear, then, that " neural blocking " due to lack of cerebral dominance

results in a transient sensory aphasia which may or may not be apparent in both visual and auditory fields, although there is a general tendency for both fields to be involved. To the extent that both fields are involved, speech and reading defects have, independently of low intelligence, a common element.

Introspective evidence. Two interesting incidents in the giving of the tests for visual and auditory aphasia lend weight to this conclusion. One *O* was having considerable difficulty with the test for auditory aphasia and as the test went on his difficulty

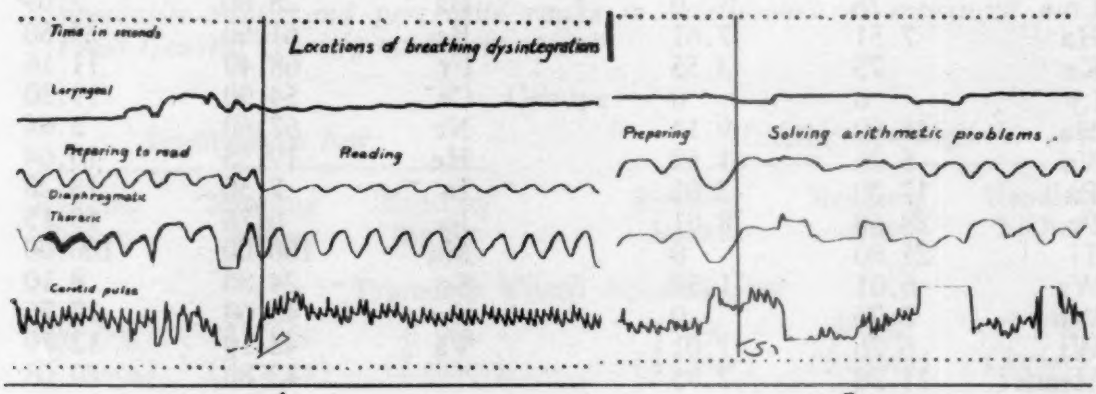

PLATE I. In the experimental series irregular breathing usually occurred at the beginning of a task. Two examples of the location of irregular breathing are shown. In case A the irregularity occurred just before the task was begun; in case B it occurred somewhat after the task was begun. The solid line reaching vertically across the entire record indicates the point at which the signal to start was given. Curves of both thoracic and diaphragmatic breathing are indicated. The top line is the record of laryngeal movements.

increased, as was common with *O*s taking this test. At the 97th presentation he had missed 29 of the numbers. Suddenly he announced that he would miss no more, and from that point on appeared to make the responses with a minimum of difficulty. The remaining responses were all correctly made. When asked to explain his "trick" he said that while before he had tried to recall the sounds of the numbers, in the latter part of the test he visualized the numbers as they were presented to him and simply "copied" from the visual image. This indicates that the transient aphasia of this subject involved his auditory imagery more particularly than his visual imagery.

Another *O*, a stutterer, reported that he could "feel" the transient auditory aphasic states "coming on". He reported

having at these times the same kinæsthetic sensations in his chest as he was accustomed to have at the onset of stuttering.

Relation of auditory imagery to control of breathing during non-speaking intervals. The close relationship between transient auditory aphasia and disorders of speech rhythm opens the question of the extent to which auditory imagery is related to control of the speech organs, particularly those involved in breathing, during non-speaking intervals. *Golla* and *Antonovitch's* (9) claim that rest breathing variability is very closely associated with auditory-motor types is not entirely substantiated by the

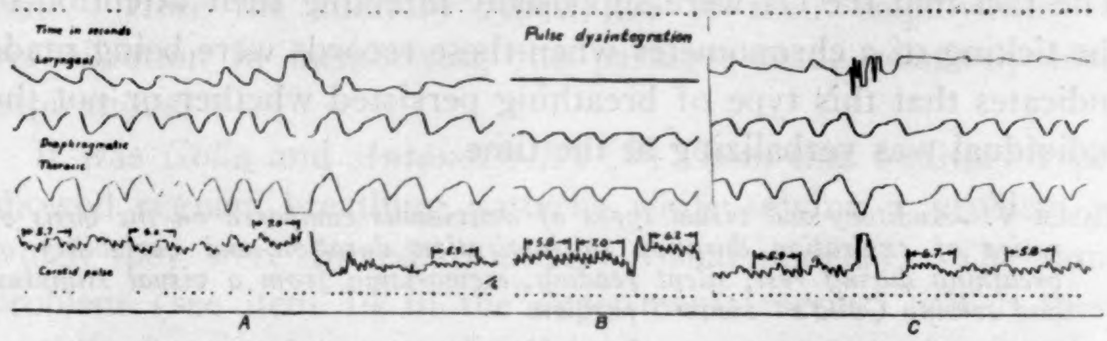

PLATE II. Irregularity in breathing was accompanied in almost every instance with a simultaneous increase in the heart-pulse rate. Three examples are shown. Measurements of the number of beats in some of the 5 sec. intervals are indicated. In case A there were 5.7 beats in the first 5 sec. interval indicated, while in the third 5 sec. interval, which was coincident with an irregularity in the breathing, there were 7.0 beats. The same sort of increase in pulse rate occurring over a very short interval of time is shown in case B. Case C is another example of the same sort of thing. As in Plate I the top line is the record of laryngeal movements, the second of diaphragmatic breathing, the third of thoracic breathing, and the bottom line a record of the healt-pulse taken from the right carotid artery.

present investigation. Table V shows a comparison between the six *O*s of the first experiment who reported habitual use of auditory imagery and the six *O*s who most definitely reported visual imagery. Of the latter group, however, *Sa* reported ability to recall very definite kinæsthetic images of such activities as playing golf, walking down the street, *etc.* It will be noticed that his breathing more nearly resembled that of the auditory group than that of the visual group into which the definiteness of his reported visual imagery required that he be placed.

The coefficients of variability for the durations of diaphragmatic expiration during rest breathing were only slightly

larger in the case of the auditory group and there is considerable over-lapping. *Golla* and *Antonovitch* report only a 7.5 per cent discrepancy between irregular breathing and auditory imagery.

Much more significant in rest breathing was the difference between the two groups in the ratios of diaphragmatic expiration durations to diaphragmatic inspiration durations. The relatively long expirations and short inspirations of the auditory types suggest breathing during overt speech. Continual employment of verbalization during silent reading and studying probably implanted a speech-like pattern of breathing in the individual. The fact that the *O*s were supposedly directing their attention to the ticking of a chronometer when these records were being made indicates that this type of breathing persisted whether or not the individual was verbalizing at the time.

TABLE V. *Auditory and visual types of individuals compared on the basis of ratios of expiration duration to inspiration duration and variability of breathing during rest, silent reading, memorizing from a visual stimulus, and solving Golla's "visual" problem*

	Ratio of expiration duration to inspiration duration: Rest	Ratio of expiration duration to inspiration duration: Silent reading	Coefficient of variation of expiration durations during rest breathing	Blocking time : total time: Memorizing from visual stimulus	Blocking time : total time: Solving Golla's visual problem
Auditory types					
Al	2.12	2.19	19.9	.6580	.1766
Br	2.27	1.86	13.1	.2622	.1486
Da	1.85	1.78	15.2	.1882	.4960
Ge	1.71	2.08	24.5	.4200	.0667
Nu	2.00	2.13	25.3	.6930	.0318
Su	2.26	2.36	25.1	.0373	.0895
Means:	2.03	2.07	20.5	.3764	.1682
Visual types					
Ba	1.85	1.40	13.3	.0866	0
Ca	1.25	1.49	18.6	.1800	.2850
De	1.46	1.49	22.0	.0138	0
Fl	1.58	1.32	13.6	.0165	.0495
Kn	1.32	1.48	14.4	0	.0375
Means:	1.57	1.51	15.4	.0707	.0620
Visual-kinæsthetic type					
Sa	1.98	1.88	10.4	.1272	0

The ratio of expiration duration to inspiration duration during the silent reading periods is also shown in Table V. About the same difference between the two groups as in rest-breathing is indicated.

The most striking difference between the two groups appears in their breathing during a period of memorizing from a visual stimulus (described under item 13 in the experimental series). The measure here used was the ratio of blocking time to total time, or the ratio of the time during which the individual was making unusually long expirations or inspirations to the total time. Here the auditory types, due to their employment of verbalization in memorizing the passage, made relatively long expirations.

It was *Golla* and *Antonovitch's* (9) claim that auditory types showed regular breathing patterns while solving a problem in which they were forced to employ visual imagery. The same problem (see item 14 in the experimental series) which these investigators used was employed in the present investigation, but with different results (see Plate III). In no case did the breathing become more regular and in most cases the problem was solved before a fair sample of breathing curves could be obtained. In Table V the ratios of blocking times to total times for visual and auditory types are shown. The auditory group is shown to be much more irregular in breathing than the visual group. That this irregularity was largely due to a tendency to verbalize on this " visual " problem could easily be observed by *E*.

In passing it is not inappropriate to remark that while *Titchener* (17) and other authorities generally agree that about 75 per cent of the population-at-large are visual types the authors of the preceding study found 29 auditory types in a group of 67 cases. The present study revealed only six clear-cut auditory types out of 38 cases.

Synchronization of breathing with mental processes. The foregoing data indicate a relatively close relationship between auditory imagery and the habitual pattern of respiration. In addition we may assume that there is also a relation between the breathing rhythm and visual imagery, although that relation is

not nearly as marked as in the case of auditory imagery. During both visual and auditory tests the breathing of all *O*s tended to be synchronized with the presentations on the tests (see Plate IV). Four general types of synchronization were employed by the *O*s. In most cases *O* would employ one of these types consistently throughout the test. The most common form of synchronization was to regulate the breathing so that each pres-

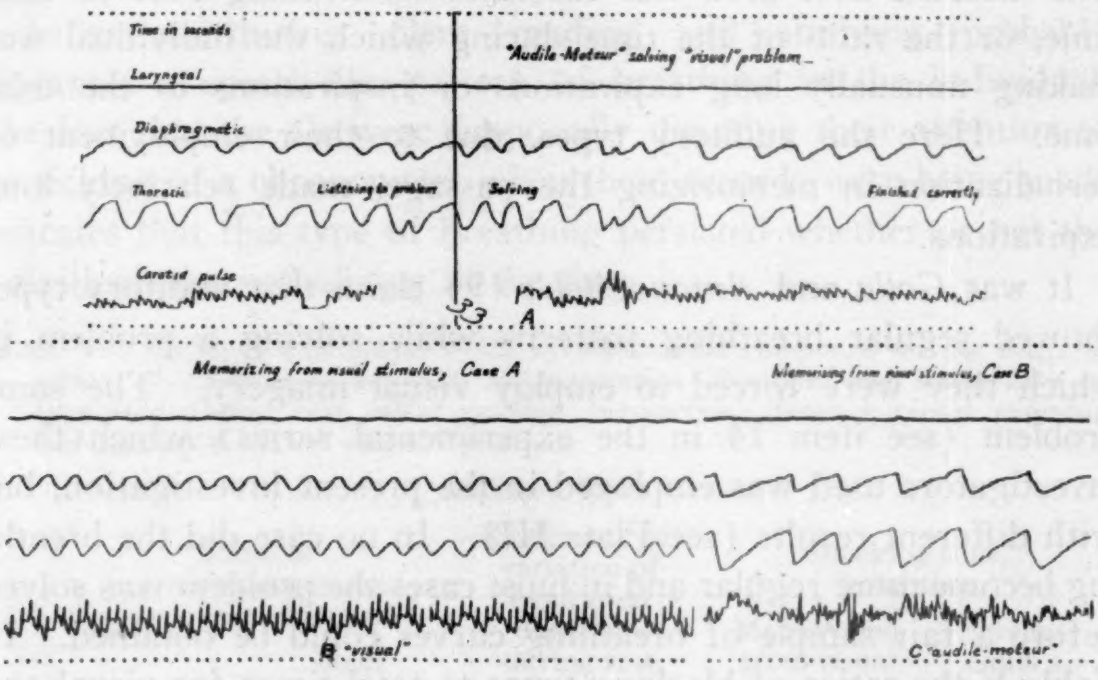

Plate III. *Golla* and *Antonovitch* (**9**) report that auditory types of individuals are irregular breathers during rest periods but that when given a "visual" problem to solve their breathing becomes regular. A shows the breathing of a typical auditory type of individual before and during the solution of the same "visual" problem upon which these investigators based their conclusion. Three points in refutation of their findings are illustrated. In the first place, breathing was not more regular during the period in which the problem was solved; secondly, the problem was solved correctly before a fair sample of breathing curves could be obtained; and thirdly, the last seven curves suggest verbalization or use of auditory-kinæsthetic imagery. The findings of this study with regard to the difference between visual and auditory types are illustrated in B and C. The most marked differences occurred during the period of memorizing a typewritten selection. Case A is the record of a visual type of *O* while memorizing the selection and Case B is the record of an auditory type of *O* while memorizing the same selection. The latter *O* was simply verbalizing or making use of auditory-kinæsthetic imagery. A similar, though much less marked, difference in the breathing curves of the two types of *O*s was observed during rest breathing.

In each record the top line indicates the laryngeal movements, the second diaphragmatic breathing, the third thoracic breathing, and the bottom line the pulse of the carotid artery. Movements of those muscles of the neck involved in breathing and in verbalization naturally affected the record of the carotid pulse.

entation occurred during an expiration. Usually the breathing was regulated so that presentations came on successive expirations. A variation of this form of synchronization occurred in the cases of some of the auditory types of *O*s; it was to regulate

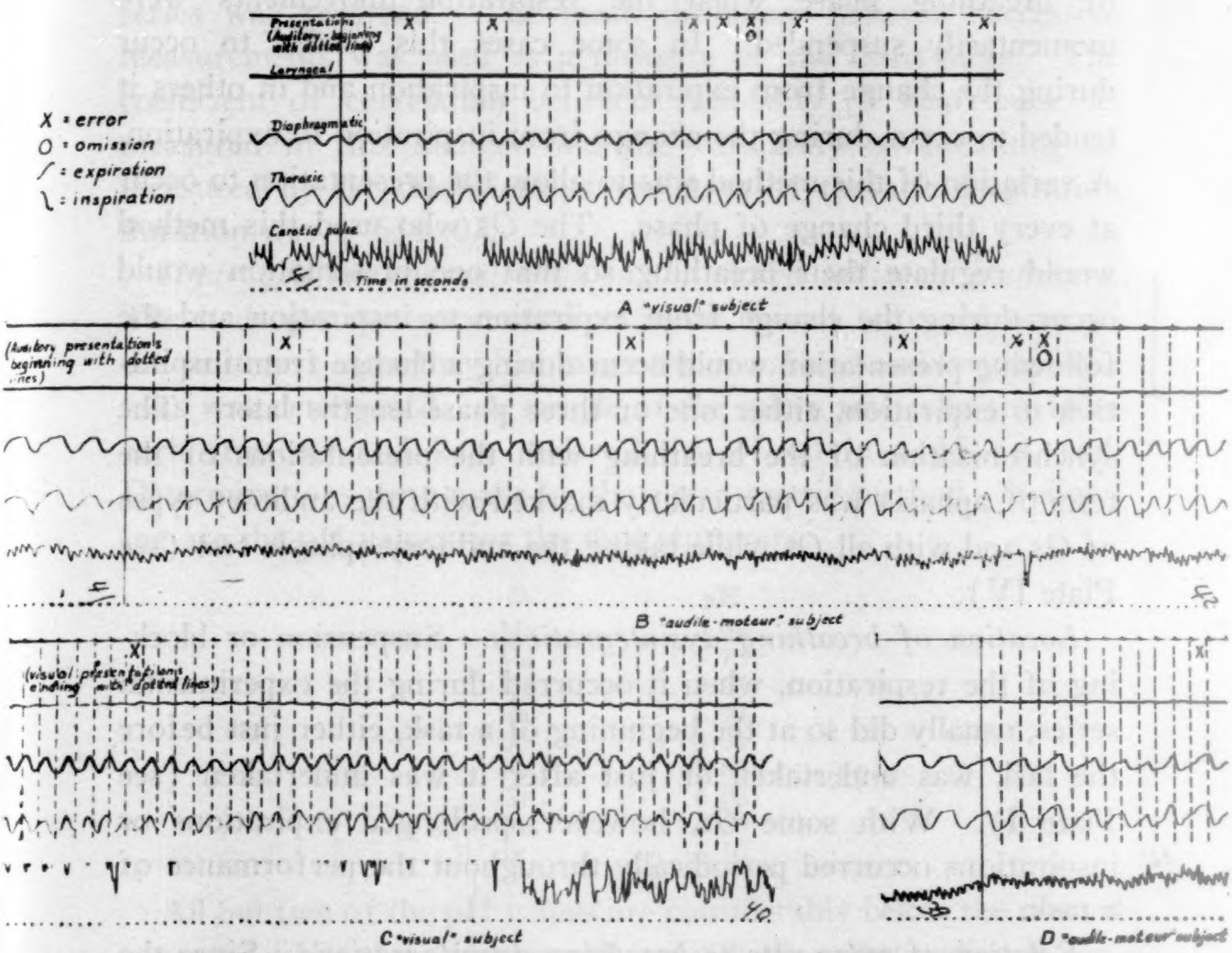

PLATE IV. Breathing of all types of individuals tended to be synchronized with the presentations in the aphasia tests. In A the vertical dotted lines indicate the point at which each presentation in the auditory aphasia test began. The record shows how the individual in nearly every instance adjusted his breathing so that the presentation would occur during his inspiration and the response would be made during his expiration. In B the record of an auditory type of individual is shown. In the same test this individual regulated his breathing so that each presentation occurred in the midst of an expiration.

In C the vertical dotted lines indicate the *end* of each presentation in the visual aphasia test. The record of a visual type of individual is shown. The breathing is shown to be regulated so that a change of phase occurs at the end of each presentation. There seems to be little consistency as to whether the change is from inspiration to expiration or from expiration to inspiration. In D the record of an auditory type of individual is shown. In this instance the breathing is regulated so that two presentations occurred on the same expiration.

each expiration so as to include two presentations (see D, Plate IV). This enabled *O* to breathe more slowly and more nearly at his normal rate. Another method of synchronization employed by some *O*s was to allow the presentation to occur at the change of breathing phase when the respiration movements were momentarily suspended. In some cases this tended to occur during the change from expiration to inspiration and in others it tended to occur during the change from inspiration to expiration. A variation of this method was to allow the presentation to occur at every third change of phase. The *O*s who used this method would regulate their breathing so that one presentation would occur during the change from expiration to inspiration and the following presentation would occur during a change from inspiration to expiration, either one or three phase-lengths later. The synchronization of the breathing with the presentations of the tests of aphasia was particularly marked with the auditory types of *O*s and with all *O*s while taking the auditory aphasia test (see Plate IV).

Location of breathing dysintegrations. Suspension or blocking of the respiration, when it occurred during the experimental series, usually did so at the beginning of a task, either just before the task was undertaken or just after it was undertaken (see Plate I). With some *O*s, however, prolonged expirations or inspirations occurred periodically throughout the performance of a task.

Relation of pulse rate to breathing dysintegrations. Since the pulse from the right carotid artery was recorded on the same record as the breathing, it was possible to observe changes in pulse rate in relation to breathing irregularities. With all *O*s the pulse rate tended to be markedly increased at the same instant that a prolonged expiration or inspiration was begun (see Plate II). Since the increase in pulse rate occurred in some cases even before the breathing phase had reached a state of prolongation, it would appear that the phenomenon can not be entirely attributed to carbon dioxide stimulation in the lungs. A more likely explana-

tion is that an underlying neural disturbance interferes with the rhythm of both heart-pulse and respiration.

As a measure of the variability of the pulse rate in individual cases the number of pulsations during every third 5 sec. period throughout the six minutes of silent reading in the experimental series was recorded. The mean difference between successive measurements was used as a measure of the heart-pulse. The coefficient of correlation between variability of heart-pulse as measured in this manner and the variability of breathing as measured by the coefficient of variation of thoracic inspiration duration was $+.63 \pm .07$.

Hydrogen ion concentration in the mixed saliva of stutterers. The hydrogen ion concentration in the mixed saliva of nine of the stutterers after they had taken the visual and auditory aphasia tests was determined. A sample of the saliva was collected from each stutterer and kept under 2 c.c. of oil in a 15 c.c. vial. Determinations were made by the electrometric method. Following are the pH values for the nine stutterers:

O	pH
Ma	7.05
Va	5.75
Ho	5.25
Ba	6.90
Sc	5.00
Fr	5.60
Gr	6.00
Sw	6.30
Ja	6.10

All but two of the pH values are considerably below the normal range of pH values for normal individuals under ordinary conditions of mental work. Accepting the interpretation of *Starr* (16) this would mean the presence of a considerable amount of carbon-dioxide in the blood, due to inefficient breathing. That the inefficient breathing in turn is due to dysintegration in the functioning of the nervous system is reasonable to suppose, since the accompanying aphasic condition is related to a peculiar neural situation.

IV. Summary of results. 1. Individuals representing cases of silent reading disability were found to be as regular in their

breathing during silent reading and associated mental processes as were normal readers.

2. Individuals representing cases of silent reading ability inconsistent with their general intelligence were found to be as regular in their breathing during silent reading and associated mental processes as were individuals whose reading ability was consistent with their intelligence.

3. Individuals whose silent reading ability was low in relation to their general intelligence were most deficient in the rhythm of their speech; individuals whose silent reading ability was high in relation to their general intelligence were least deficient in the rhythm of their speech; and individuals whose silent reading ability was consistent with their intelligence were midway between the other two groups in the rhythm of their speech.

4. Individuals who were diagnosed as deficient in the rhythm of their speech were found to be not only low in silent reading ability but low in proportion to their intelligence.

5. Silent reading comprehension and speech comprehension were not found to be highly correlated.

6. Individuals who were diagnosed as speech defectives, as a group, did not show any significant silent reading disability.

7. Individuals who were diagnosed as deficient in ability to organize a speech were deficient in neither sentence organization nor paragraph organization in silent reading.

8. None of the following aspects of speech were significantly correlated with silent reading ability: articulation, voice, organization of materials in a speech, symbolic formulation and expression.

9. Left handed and ambidextrous individuals were found to be not only low in silent reading ability but low in proportion to their intelligence.

10. Transient visual aphasia was found to be associated with silent reading disability independently of intelligence.

11. Transient auditory aphasia was found to be associated with stuttering.

12. The rest-breathing of auditory-motor types of individuals

was found to be nearly as regular as the rest breathing of visual types of individuals.

13. The duration of expiration among auditory types at all times, but especially when memorizing from a visual stimulus, was relatively long as compared with the duration of inspiration.

14. Breathing of both visual and auditory types of individuals was found to be synchronized with successive presentations of visual or of auditory stimuli in the aphasia tests.

15. Suspension or blocking of breathing, when it occurred, was most apt to occur at the beginning of a task.

16. Heart-pulse rate was found to increase momentarily during prolonged expirations or inspirations.

17. Variability in heart-pulse rate was highly correlated with variability in breathing rhythm.

18. Hydrogen ion concentration in stutterers after taking the aphasia tests was generally high.

V. Major conclusions. 1. The connection of reading disability to defective speech rhythm and of defective speech rhythm to reading disability independent of general intelligence indicates a common element of an essentially transient nature in speech and reading defects.

2. The connection of speech rhythm defects, such as stuttering, to lack of cerebral dominance—according to *Travis* (18)—and the connection of reading disabilities independent of intelligence to lack of cerebral dominance indicates the same sort of neurological condition underlying each type of defect.

3. The more particular connection of transient visual aphasia to reading disability and of transient auditory aphasia to stuttering indicates a certain amount of differentiation between the sensory fields affected by the underlying neural situation.

4. Neural blocking, due to a lack of cerebral dominance, results in a transient sensory aphasia which may or may not involve both visual and auditory sensations.

5. To the extent that transient aphasia involves both visual and auditory sensations, speech and reading defects have, independently of low intelligence, a common element.

VI. Minor conclusions. 1. A pattern of breathing resembling that necessary for the production of overt speech implants itself upon those individuals who customarily employ auditory-kinæsthetic imagery in the mechanism of their thought.

2. The rhythm of breathing tends to be synchronous with the rhythm of thought or fluctuations of attention over short-time intervals.

3. The rhythm of breathing is closely associated with the rhythm of the vaso-motor system and interruptions in the former alter the rate of the latter.

4. Most stutterers have a high hydrogen ion concentration.

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THE REMNANT CAPACITIES OF THE FEEBLE-MINDED[1]

by

WILLIAM E. MCCLURE

I. Introduction. It is well known that individuals differ in their capacities or abilities in so far as it is possible to measure different traits by means of intelligence, educational, and special aptitude tests. In other words, judging from their performances on various tests, most people show an unevenness of development in the many traits.

This unevenness of development has been shown to exist in the feeble-minded as well as in the normal individuals. Tredgold (36), from his own observations and those of others, gives several instances of feeble-minded persons with certain abilities far above their general mental level. He refers to them as *idiots savants.* These observations point to the necessity of making a careful study of subnormals for the purpose of discovering these special abilities. A knowledge of such abilities would be of service in adjusting these people to their environment, whether that environment be institutional life, home life, or any other type of life.

II. The problem. In this study an analysis was made of the performances of a group of feeble-minded male subjects on a battery of mental, educational, and special aptitude tests to determine if there existed any special abilities not commonly found in normal boys who have the same mental age. A significantly high score on a test was considered an indication of a special ability, or a *remnant capacity.* Inversely, a significantly low score on a test was considered an indication of an exceptional lack of ability, or a *depression.* Any score made by a feeble-minded subject was

[1] This study was suggested by Dr. C. E. Seashore and completed under the direction of Dr. F. B. Knight.

considered significant if it was at least one standard deviation above or below the average score made on the same test by a control group of normal boys.

III. Procedure. Each group, the feeble-minded group and the normal group, contained 41 subjects. The selection of these subjects was based on their chronological and mental ages. Their mental ages were determined by the Stanford revision of the Binet-Simon test (33).

The chronological age limits for the feeble-minded were 16 years and over, and the mental age limits were from eight yrs. six mos. to nine yrs. six mos. For the normal group the chronological age limits were from eight yrs. ten mos. to nine yrs. two mos., and the mental age limits were the same as for the feebleminded.

All of the tests used, with only one exception[2], are fully described in the literature in the field of testing. They are shown in the following list. Some are listed more than once because they measure more than one trait. The Mare and Foal test, for example, is scored by the number of seconds required for performing it as well as by the number of errors made during its performance. Thus it is listed as two separate tests, first as *Mare and Foal (time)* and second as *Mare and Foal (errors)*. In all the tables and graphs throughout this study the numbers representing the tests correspond with the tests in this list bearing the same numbers.

These tests were all administered and scored according to the directions given in their respective manuals of directions.

Pintner-Paterson Scale of Performance Tests (23)

1. Mare and Foal (time)
2. Mare and Foal (errors)
3. Seguin Form Board (time)
4. Five Figure Form Board (time)
5. Five Figure Form Board (errors)
6. Two Figure Form Board (time)
7. Two Figure Form Board (moves)
8. Casuist Form Board (time)

[2] The Eighty-one Cube Test. This test was suggested by Dr. H. H. Goddard. It is a construction test composed of 81 one-inch cubes and designed to measure the ability to follow directions. Success depended upon the ability to select certain blocks and to place them in their proper positions.

9. Casuist Form Board (errors)
10. Manikin Test (time)
11. Manikin Test (score)
12. Feature Profile (score)
13. Ship Test (time)
14. Ship Test (score)
15. Picture Completion (time)
16. Picture Completion (score)
17. Knox Cube Test
18. Substitution Test (time)
19. Substitution Test (errors)
20. Substitution Test (score)

Porteus Maze Test (25)

21. Porteus Maze Test

Whipple-Healy Tapping Test (9)

22. Tapping Test (speed)
23. Tapping Test (errors)
24. Tapping Test (index)

Eighty-one Cube Test[3]

25. Eighty-one Cube Test

Army Alpha Test (39)

26. Test of Common Sense (Test 3)
27. Test of General Information (Test 8)

Ohio Literacy Test (5)

28. Ohio Literacy Test (score)
29. Ohio Literacy Test (no. wrong)

Stenquist Mechanical Aptitude Test I (30)

30. Stenquist Mechanical Aptitude Test I

Pintner Educational Survey Test (22)

31. Vocabulary Test
32. Arithmetic Test
33. Kelley Reading Test
34. Thorndike Reading Test
35. Trabue Completion Test
36. Grammar Test
37. Geography Test
38. History Test

Myers Mental Measure (16)

39. Following Directions Test
40. Picture Completion Test
41. Test of Common Elements (with time limit)
42. Test of Common Elements (with no time limit)

Kent-Rosanoff Association Test (27)

43. Association Test (reaction time)
44. Association Test (common reactions)

[3] *Ibid.*, 2.

IV. Statistical treatment. To convert the raw scores made on the various tests into comparable scores *Kelley's* formula for standard scores was used (**13**, p. 115), which is as follows: $Z = \frac{X - M}{\Sigma}$. In this formula Z is the standard score, X the raw score, M the arithmetic mean of the total number of scores on each test, and Σ the standard deviation from the mean of the total number of scores on each test.

Because of the small number of cases used in this study the median was used for the point of central tendency rather than the mean. *Rugg* says, " . . . the median may give a more stable average from the small samplings, due to the fluctuation in the size of extreme values " (**28**, p. 145).

Since the median was used to denote the point of central tendency of the scores of each test it was necessary to compute the standard deviations from the medians. This is not commonly done but *McCall* says, " Like the Mn.D., the S.D. may be computed from any average or measure of central tendency whether mode, median, or mean " (**14**, pp. 383–87). Table I shows the median standard score and the standard deviation of each test.

V. Selecting the remnant capacities. Studies have been made by *Kelley* (**12**, pp. 321–33), *DeVoss* (**4**), and *Brown* (**2**) which suggest methods of determining significant differences between scores of several individuals on the same test. In this study the criterion for selecting the exceptional scores was the commonly accepted measure of variability, the standard deviation.

Thus if a feeble-minded subject made a score on any test at least one standard deviation above the median score of the normal control group on the same test he was considered to have a remnant capacity in the ability measured by that test. If, on the other hand, he made a score at least one standard deviation below the median score of the normal control group he was considered to have a depression.

A comparison of the median performances of the two groups is shown in Fig. 5. The median performances of the normal control group are represented by the straight heavy black line extending from " O ". The medians of the feeble-minded are

represented by the heavy irregular curve. The two broken lines represent the distances of plus and minus one standard deviation from the medians of the normals. The number of remnants made by the feeble-minded on each test are given in the column tabulated "remnants" and the depressions are given in the

TABLE I. *The median standard scores and standard deviations for the feeble-minded and the normal groups*

Test	F.M. median standard score	F.M. standard deviation	Normal median standard score	Normal standard deviation
1	.46	1.04	.26	.94
2	.60	1.25	.09	.85
3	.64	.92	—.49	.72
4	.31	1.08	.26	1.01
5	.18	.42	.31	.70
6	.48	.73	.24	1.23
7	.45	.77	.30	1.28
8	.37	.75	.44	.82
9	.17	.29	.44	.69
10	.36	1.14	.18	.87
11	—.27	1.15	.69	.88
12	.35	.94	—.85	1.24
13	.51	.76	—.05	1.14
14	—.17	1.08	.20	.91
15	.50	1.17	.04	.88
16	.07	1.08	.22	.97
17	—.07	1.08	.48	.89
18	.18	1.34	.08	.57
19	.13	1.36	.35	.29
20	.21	1.33	.18	.37
21	.45	1.58	.01	.74
22	.49	1.19	—.36	.58
23	.07	.97	.07	1.04
24	.58	1.18	—.35	.61
25	—.45	1.27	—.29	.86
26	—.25	.28	.16	1.05
27	.16	1.22	—.37	.55
28	.12	.97	—.04	.89
29	.14	.81	.14	1.08
30	.10	1.26	—.33	.60
31	—.02	.13	—.02	.08
32	—.43	1.09	.33	.77
33	.00	1.71	.00	2.81
34	—.47	.95	.46	1.24
35	—.06	.99	.65	1.04
36	—.14	.35	—.14	.34
37	—1.05	1.37	—1.05	.43
38	.14	1.12	—.35	.39
39	—.66	1.18	.08	.84
40	—.33	1.19	—.08	.82
41	—.16	.88	.46	1.11
42	—.37	1.15	—.16	.98
43	—.01	1.05	.41	.77
44	—.03	.88	.20	1.08

column tabulated "depressions". To illustrate, the first test, Mare and Foal (time), is shown to have two remnants and five depressions, which means that the scores made by two of the feeble-minded subjects were so high that they deviated more than one Σ above the median of the normals on that test, and the scores made by five of them deviated more than one Σ below the median of the normals.

This chart shows the variation of the medians made by the two groups. The medians made by the feeble-minded on four of the tests are shown to be more than one standard deviation above the medians of the normals while on only one test are they more than

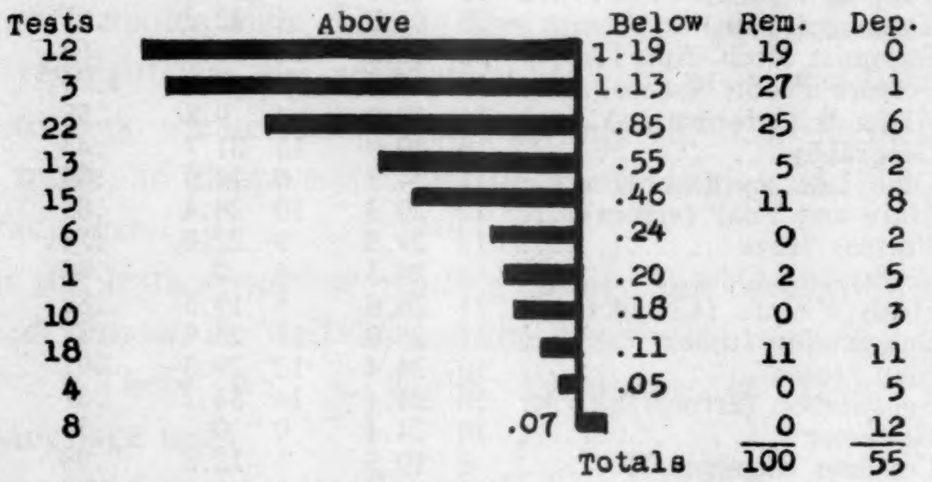

FIG. 1. Speed on performance tests; median scores of the feeble-minded above and below the medians of the normals, and the remnants and depressions on each test.

one standard deviation below the median of the normals. On six of the tests both groups have the same medians.

VI. Analysis of the tests. The feeble-minded made the largest number of remnants on two of the tests which measure speed of eye-hand coördination and the test of history. Over 60 per cent of them made remnants on each of these tests. On the test of judgment of mechanical relationship 48.8 per cent made remnants while only 26.8 per cent made depressions.

On the type of tests which require a knowledge of general facts, such as Alpha 8 and the Geography and History tests, the feeble-minded ranked high also. On the History test 63.4 per cent made remnants and 24.4 per cent made depressions. On Alpha 8 test 39.0 per cent made remnants and 9.8 per cent made

depressions. On the Geography test remnants were made by 39.0 per cent and depressions by 31.7 per cent.

The average performance on the group of eight educational tests was at about the fourth grade level. They ranked highest

TABLE II. *Remnants and depressions made by the feeble-minded on each test and the percentage of feeble-minded making them; Also the S.D.'s for both groups of subjects (tests are listed in order of number of remnants made on each)*

Tests	Name of test	Rem.	Per cent	Dep.	Per cent	S.D. Normals	S.D. Feeble-minded
3	Seguin (time)	27	65.9	1	2.4	.72	.92
38	History	26	63.4	10	24.4	.39	1.12
22	Tapping (speed)	25	61.0	6	14.6	.58	1.19
24	Tapping (index)	25	61.0	5	12.2	.61	1.18
30	Stenquist Mech. Apt. I	20	48.8	11	26.8	.60	1.26
12	Feature Profile (score)	19	46.3	0	0	1.24	.94
27	Alpha 8 (information)	16	39.0	4	9.8	.55	1.22
37	Geography	16	39.0	13	31.7	.43	1.37
28	Ohio Literacy (score)	14	34.2	6	14.6	.89	.97
2	Mare and Foal (errors)	12	29.3	10	24.4	.85	1.25
21	Porteus Maze	12	29.3	9	22.0	.74	1.58
25	Eighty-one Cube	12	29.3	0	0	.86	1.27
15	Healy Picture (Compl. time)	11	26.8	8	19.5	.88	1.17
18	Substitution (time)	11	26.8	11	26.8	.57	1.34
14	Ship (score)	10	24.4	12	29.3	.91	1.08
20	Substitution (errors)	10	24.4	14	34.2	.37	1.33
36	Grammar	10	24.4	0	0	.34	.35
42	Common Elements II	8	19.5	5	12.2	.98	1.15
40	Myers Picture Compl.	8	19.5	8	19.5	.82	1.19
16	Healy Picture Compl. (score)	7	17.1	13	31.7	.97	1.08
29	Ohio Literacy (no. wrong)	6	14.4	5	12.2	1.08	.81
13	Ship (time)	5	12.2	2	4.9	1.14	.76
39	Following Directions	5	12.2	15	36.6	.84	1.18
17	Knox Cube	4	9.8	17	41.5	.89	1.08
26	Alpha 3 (common sense)	3	7.3	11	26.8	1.05	.28
31	Vocabulary	3	7.3	0	0	.08	.13
32	Arithmetic	3	7.3	16	39.0	.77	1.09
41	Common Elements I	2	4.9	14	34.2	1.11	.88
1	Mare and Foal (time)	2	4.9	5	12.2	.94	1.04
44	Kent-Rosanoff (react. time)	2	4.9	5	12.2	1.08	.88
33	Kelley Reading	1	2.4	7	17.1	2.81	1.71
43	Kent-Rosanoff (com. react.)	1	2.4	18	43.9	.77	1.05
4	Five Figure Board (time)	0	0	5	12.2	1.01	1.08
5	Five Figure Board (errors)	0	0	10	24.4	.70	.42
6	Two Figure Board (time)	0	0	2	4.9	1.23	.73
7	Two Figure Board (moves)	0	0	2	4.9	1.28	.77
8	Casuist (time)	0	0	12	29.3	.82	.75
9	Casuist (errors)	0	0	12	29.3	.69	.29
10	Manikin (time)	0	0	3	7.3	.87	1.14
11	Manikin (score)	0	0	20	48.8	.88	1.15
19	Substitution (errors)	0	0	15	36.6	.29	1.36
23	Tapping (errors)	0	0	4	9.8	1.04	.97
34	Thorndike Reading	0	0	12	29.3	1.24	.95
35	Trabue Completion	0	0	18	43.9	1.04	.99

on the History test with 26 remnants, next on the Geography test with 16 remnants and third on the Grammar test with 10 remnants. Their performance was very poor on the two reading tests, on the Completion test, the Vocabulary test, and the Arithmetic test.

In their ability to remember directions and to follow them, the feeble-minded did not rank very high. On the Eighty-one Cube test 12 made remnants, on the Knox Cube test four made remnants, and on the test of following directions (Myers) five made remnants.

The feeble-minded ranked lower in accuracy of performing on the performance tests than in the speed of performing. Their total remnants on the speed tests (11 in no.) was 100, while their total on the accuracy tests was only 45. On the other hand they made 55 depressions on the speed tests and 114 on the accuracy tests.

On the tests requiring reading ability the feeble-minded performed almost as well as on the tests not requiring reading ability. There was a slight advantage in favor of the non-language tests.

No remnants were made on the group of performance tests requiring that several blocks be fitted into the same aperture. On the other hand an average of 11.8 remnants was made on the tests that require only one block be fitted into each aperture.

On the Kent-Rosanoff Association test only two remnants were made on the time of reaction and only one remnant on common reactions. Thus, it is shown that they rank very low on tests of speed of mental reaction such as the Kent-Rosanoff Association test and the test of Common Elements II, while their quickest reaction time appears on tests of motor speed.

On the tests requiring the ability to see a missing part and to supply it such as on the two Picture Completion tests (Healy and Myers), and on the Mare and Foal test their average was about nine remnants.

VII. Speed and accuracy on performance tests. All of the performance tests were divided into two groups, speed tests and

accuracy tests. Fig. 1 represents the speed tests showing just how much each median score of the feeble-minded group is above or below the median score of the normal group. Ten of the 11 tests measuring speed are shown to be above the medians of the normals while only one is below. Fig. 2 shows that on the accuracy tests the feeble-minded made only two medians that are above the medians made by the normals while they made eight that are below.

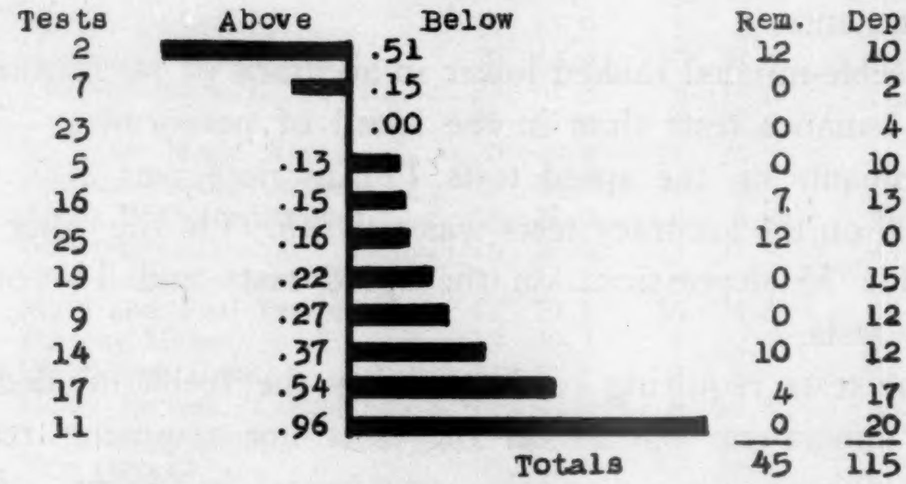

FIG. 2. Accuracy on performance tests; median scores of the feeble-minded above and below the medians of the normals, and the remnants and depressions on each test.

Figs. 1 and 2 also show the number of remnants and depressions made by the feeble-minded. They show that 100 remnants were made on the speed tests while only 45 were made on the accuracy tests. On the other hand they made 115 depressions on the accuracy tests and only 55 on the speed tests.

VIII. Language versus non-language tests. Twelve of the tests required a reading ability for successful performance while 32 required no reading ability.

Fig. 3 shows that on the 32 tests requiring no reading ability the feeble-minded have medians above the medians of the normals on 16 tests, and on 15 tests they have medians below the normals. On one test the medians are equal.

Fig. 4 shows that on the 12 tests requiring reading ability the medians of the feeble-minded are above the normals on three tests and below on four. On five of the tests they are equal.

Figs. 3 and 4 show that the average number of remnants and depressions for each test is about the same. The mean number of remnants for the reading tests is 8.0 and the mean number of depressions is 8.5. For the non-reading tests the mean number of remnants is 7.4 and the mean number of depressions is 8.5.

Taking all into consideration it seems that the feeble-minded were not handicapped to any significant degree on the tests requiring reading ability.

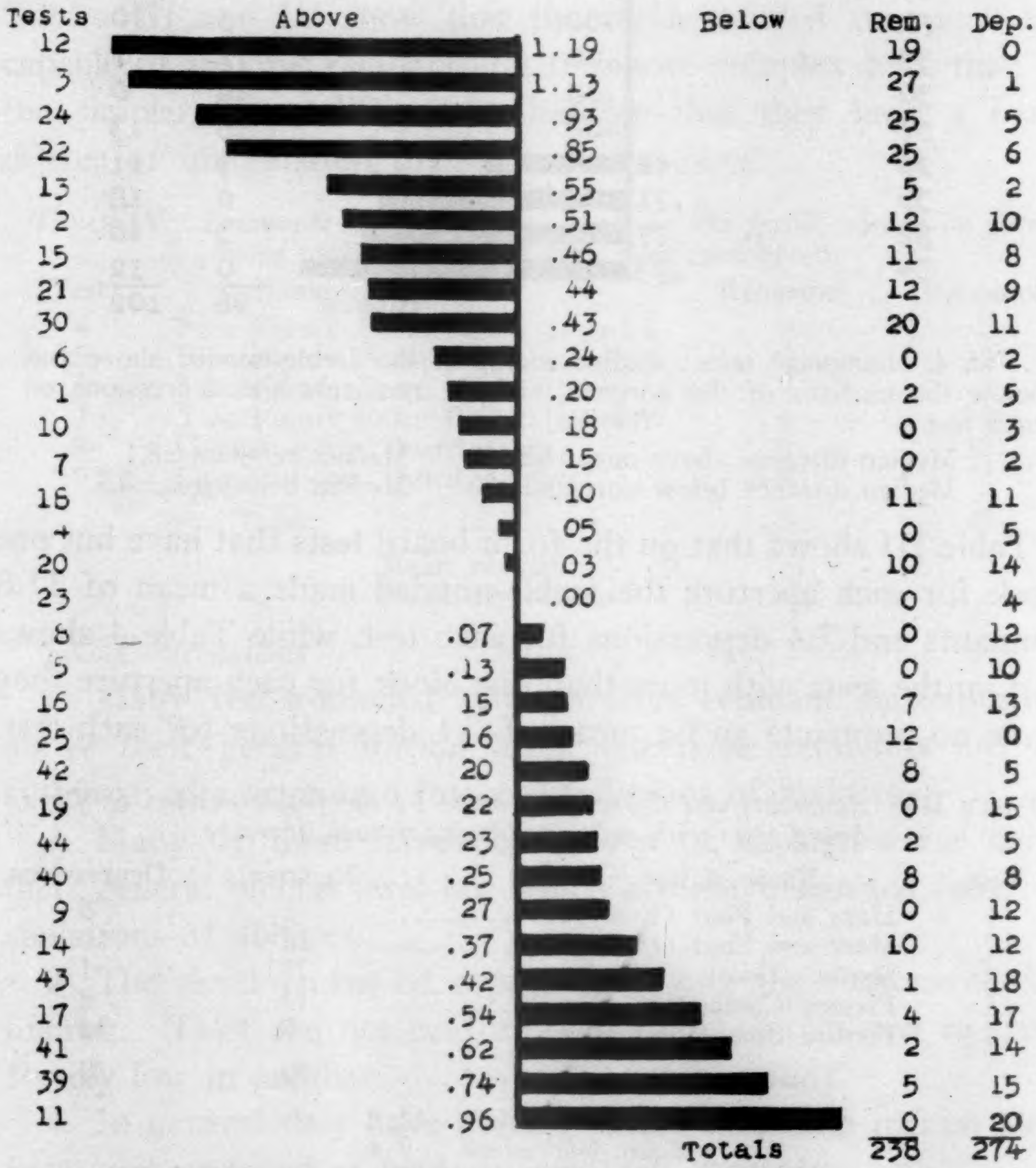

Fig. 3. Non-language tests; median scores of the feeble-minded above and below the medians of the normals, and the remnants and depressions on each test.

Mean distance above normals=.46 Mean remnant=7.4
Mean distance below normals=.35 Mean depression=8.5

IX. Comparison of form boards with only one block to each aperture with those having more than one block. The Ship test, the Manikin test, and the Feature Profile test were omitted from this comparison because they were not considered to belong to either of these groups.

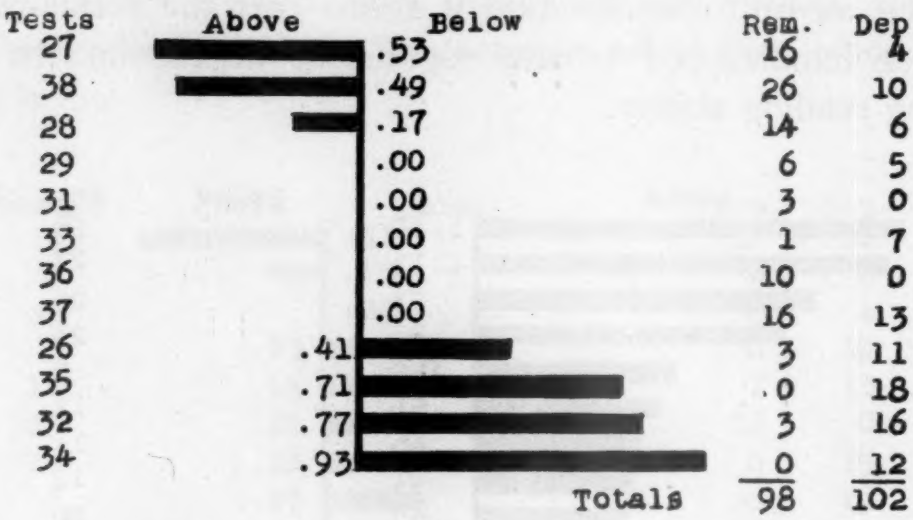

FIG. 4. Language tests; median scores of the feeble-minded above and below the medians of the normals, and the remnants and depressions on each test.

Median distance above normals=.40 Median remnant=8.1
Median distance below normals=.70 Median depression=8.5

Table III shows that on the form board tests that have but one block for each aperture the feeble-minded made a mean of 11.8 remnants and 7.4 depressions for each test, while Table 4 shows that on the tests with more than one block for each aperture they made no remnants and a mean of 7.1 depressions for each test.

TABLE III. *Remnants and depressions made by the feeble-minded on form board tests with only one block for each aperture*

Test	Name of test	Remnants	Depressions
1	Mare and Foal (time)............	2	5
2	Mare and Foal (errors)...........	12	10
3	Seguin (time)....................	27	1
15	Picture Completion (time).........	11	8
16	Picture Completion (score).........	7	13
	Total........................	59	37

Mean remnants 11.8
Mean depressions 7.4

The tests with more than one block for each aperture are much more complex than those with only one block. The data in

Tables III and IV show that the feeble-minded are much less capable of making remnants on the more complex tests than on the simpler tests. This may indicate that they have a lower degree of imagination than the normal boys.

TABLE IV. *Remnants and depressions made by the feeble-minded on form board tests with several blocks for each aperture*

Test	Name of test	Remnants	Depressions
4	Five Figure Form Board (time)...	0	5
5	Five Figure Form Board (errors)..	0	10
6	Two Figure Form Board (time)...	0	2
7	Two Figure Form Board (moves)..	0	2
8	Casuist Form Board (time).......	0	12
9	Casuist Form Board (errors)......	0	12
	Total........................	0	43

Mean remnants 0
Mean depressions 7.1

IX. Conclusions

1. Many feeble-minded subjects have remnant capacities far above their general mental level, but these remnants are not systematically organized into constellations of abilities.

2. Many of them have depressions of capacities far below their general mental level but which are not organized into constellations of abilities.

3. The development of capacities among the feebleminded is uneven. They are not uniformly high in one subject nor uniformly low in another.

4. In general they have greater motor skill than mental alertness, greater speed of performance than accuracy.

5. Their ability to follow directions is not developed in proportion to some of the other skills.

6. They are only slightly below their general mental level in reading ability.

7. Their general ability to synthesize scattered impressions into wholes is not developed beyond their general level of intelligence.

8. Their average accomplishment in the various school subjects is almost equivalent to their general mental level although their abilities in the different subjects are not evenly developed.

9. They are above their general mental level in general information.

10. Their knowledge of mechanical relationships is above their general mental level.

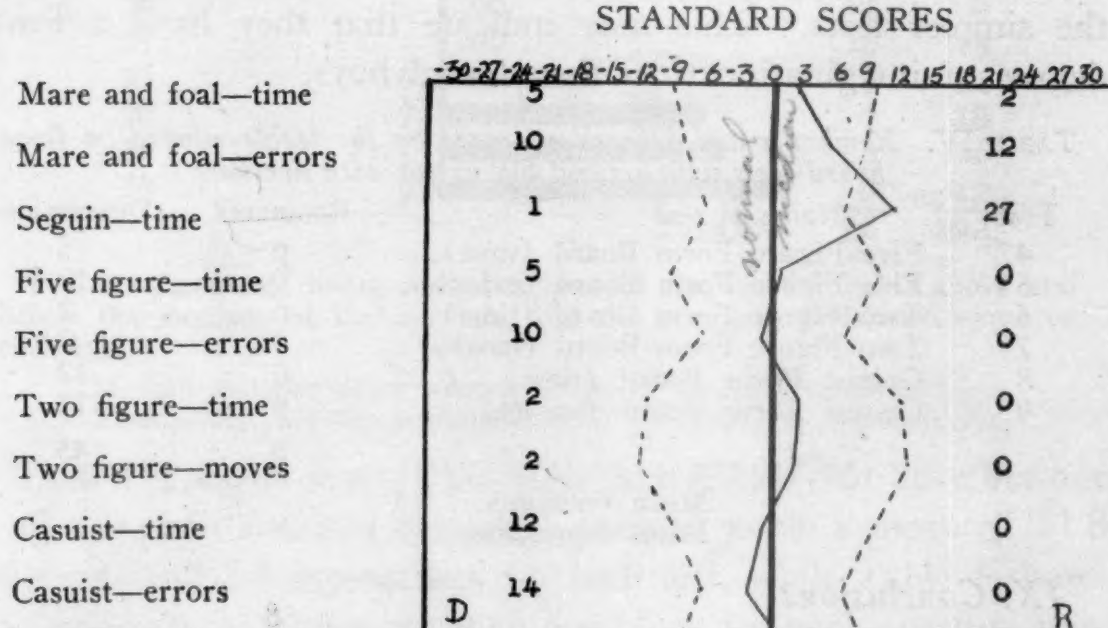

FIG. 5. Remnants and depressions of the feeble-minded.

The straight line from the standard score "O" represents the median performances of the normal group, the irregular line represents the median performances of the feeble-minded group, the two broken lines represent the distances plus and minus one standard deviation from the medians of the normals, and the two columns of figures show the number of remnants and depressions made by the feeble-minded on each test.

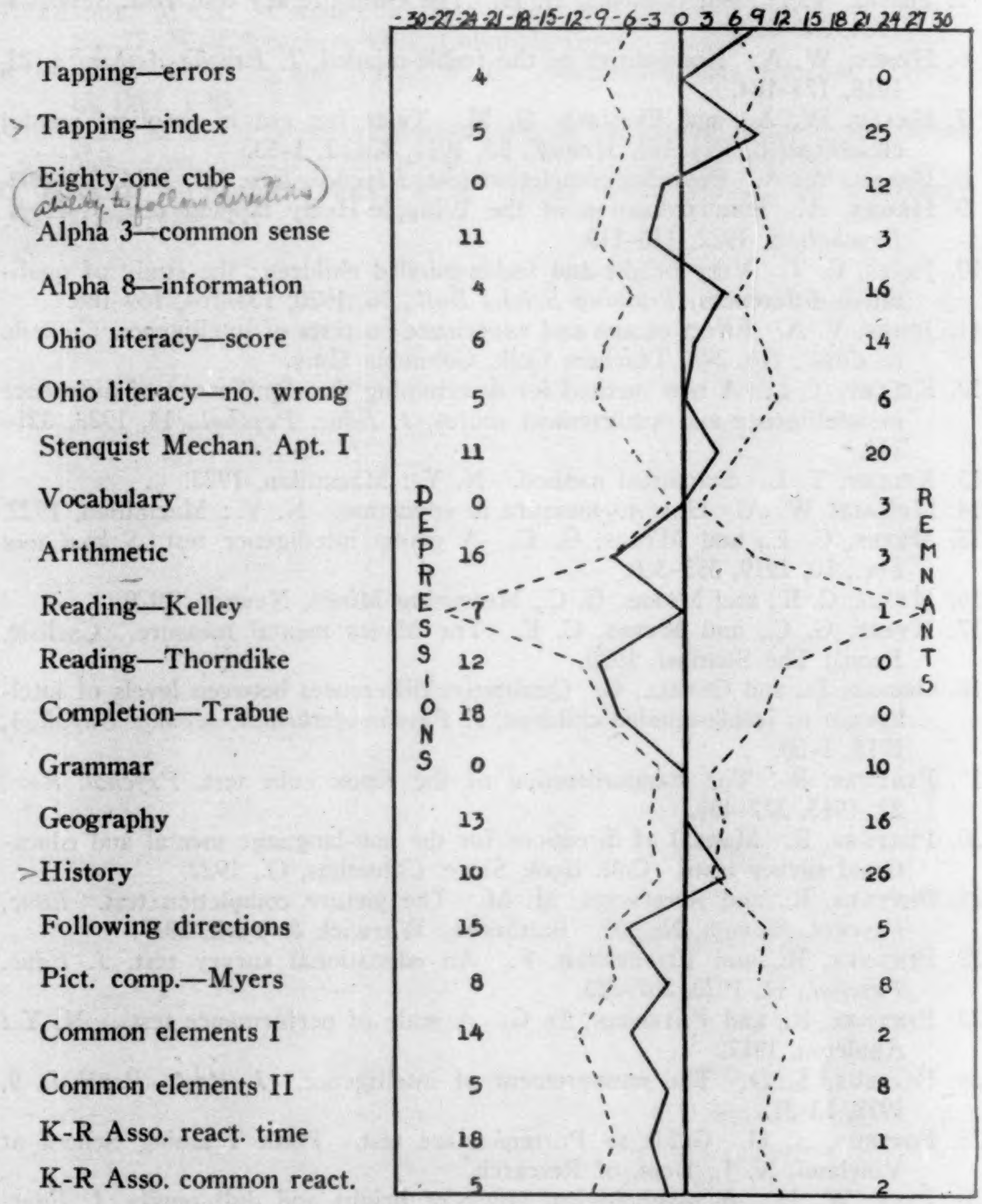

FIG. 5 (cont.)

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DYSINTEGRATION OF BREATHING AND EYE-MOVEMENTS IN STUTTERERS DURING SILENT READING AND REASONING

by

Elwood Murray

I. Introduction. The object of this study was to investigate the dysintegrations that occur in stutterers during silent reading and reasoning. Two problems were of particular concern in this experiment: (1) The form of and the extent to which dysintegrations may occur in breathing and in eye-movements while stutterers read silently or reasoned; and (2) the extent to which stutterers may be deficient in comprehension and rate of reading as indicated by standardized reading tests.

Interest of the casual observer of stuttering is almost always confined to those more or less violent and radical outward manifestations familiar to all in the conversation of the typical stutterer. The influence on speech is often so drastic and demoralizing to effectiveness that individuals who come into contact with stutterers can only look on in amazement at what they actually see and hear. And, as will be demonstrated in the next section, the curiosity of investigators as to the nature of this malady has also been very largely limited to those external aspects most directly observable; namely, the overt speaking and oral reading of stutterers. Many of the remaining more subtle and concealed activities of the stutterer have aroused small concern as to their possible anatomical, physiological, or psychological aberrations.

Our concern in stuttering was in its implicit side. It is not only useful, but necessary, to know to what depths the disturbances and disharmonies so noticeable in the conversation of stutterers extend in the nervous system; to know whether or not the individual has similar difficulties in activities other than those of explicit speaking.

Most closely related to overt speech are the inner activities of silent reading and reasoning. Appropriately, therefore, arises the question, whether individuals who have such radical and far-reaching disturbances during overt speaking may not also have to some undetermined extent similar mal-functionings in regard to their inner and more subtle activities of silent reading and reasoning. As will be revealed in the survey of investigations relating to stuttering in the next section, there are various dysintegrations, or inco-ordinations, and irregularities among the different neuro-muscular mechanisms employed in speaking. Instead of the different parts working together to bring about smooth and controlled speech, there are found antagonisms, blocks, spasms, and other breakdowns in functionings among the various musculatures employed. As the survey of experimental studies on breathing will reveal, the individual during stuttering does not perform as a unified whole; the abnormalities exhibited are evidence of different parts working separately—in effect, functional dysintegrations. Our purpose in this study was to find out whether these same phenomena occur to any comparable extent and form during silent reading and reasoning.

In order to obtain data on silent reading and reasoning that can be used for comparison with the data that have been derived from the studies of explicit speech, the factors to be studied must be analogous to those in the investigations that have been made. The only aspect common to both stuttering and silent reading that has been studied thus far is that of breathing. And much the same technic of investigation can be used to examine breathing during silent reading and reasoning as has been used by other experimenters in regard to propositional speech and overt reading. One of the most important concerns of this study, therefore, is with the breathing of stutterers. We have attempted to ascertain to what extent phenomena of breathing similar to that of overt speaking and reading occur in the more subtle and implicit activities of silent reading and reasoning.

A study of silent reading, moreover, offers an excellent opportunity to observe dysintegrations from another and important aspect and in a manner that is scientifically adequate. Reading

presents an additional motor manifestation that is open to observation, *i.e.,* the movements of the eyes as they travel along the lines of the reading matter across the page. Of all the mechanisms employed in the performance of silent reading the most important and the most open to inquiry are those of eye-movements. Equipped as they are with a very delicate muscular system and with a complicated nervous control, the eyes must be of primary interest in any study of dysintegrations concerned with reading. Since the procedures available for the study of ocular movements make it possible to present comparisons with analogous factors in breathing movements, such an investigation is especially desirable.

What may be indirectly a criterion of dysintegration is to be found in the use of standardized silent-reading tests to ascertain the efficiency of the stutterer in both the rate and the comprehension of reading. These tests should be of assistance in determining whether stutterers as readers are more or less efficient than normal individuals, and in what phase of the reading process they may be peculiar. Of particular interest is the determination whether there exists any relation between the amount of dysintegration of breathing and ocular movements, and the efficiency of the stutterer in either comprehension or rate of reading. Since the experiment employed a control group of non-stutterers, the question may be applied to them also.

II. History. The several types of studies on record closely enough related to provide data that may be used for comparative purposes are as follows: (1) studies of breathing in non-stutterers during "mental" work; (2) studies of breathing in relation to normal speech; (3) studies of breathing in relation to normal oral reading; (4) studies of breathing in relation to stuttering during overt speech and reading; (5) studies of ocular movements in non-stutterers who are good silent readers; and (6) studies of ocular movements in non-stutterers who are poor silent readers.

Most closely related to the present study is the work of *Skaggs* (29). He studied 21 normal subjects for changes in breathing and pulse under the differing conditions of rest and

relaxation, mental work upon problems in mental multiplication, "excited expectancy", and following the administration of a shock. Regarding breathing he found the following: (1) A period of mental work produced the most shallow breathing; mental relaxation produced a greater amplitude of breathing; excited anticipation resulted in a still greater amplitude; and the period following the shock resulted in the greatest depth of breathing. This held for both thoracic and abdominal breathing. (2) Breathing amplitude increased in variability with the increase of emotional elements in the situation. (3) Subjects breathed fastest in mental work and slowest in relaxation. Breathing was most regular in a period of relaxation. (4) Breathing was most shallow in mental multiplication and deepest in the half minute following the shock (noise). (5) Breathing waves occurred most regularly in a condition of mental-physical relaxation; they occurred less regularly in mental work and least regularly in the emotional conditions.

In regard to breathing duing normal speech the only experimental work on record is by *Travis* (34). He found that there was an integration of the various units of the breathing mechanism which exhibited the following characteristics: (1) a fairly close correspondence between thoracic and abdominal breathing; (2) a relatively greater number of laryngeal than of breathing movements; (3) a relatively complete independence between vertical movements of the larynx and of changes in breath pressure; (4) a disproportionate increase in duration of expiration during speech; and (5) the presentation by the abdomen of small in and out movements at a rate varying from five to seven a second.

The studies of breathing in relation to oral reading in normal speakers are somewhat less limited in number. *Scripture* (28) has reported the fact that any word or phrase is uttered with a single continuous action and is not broken up into units corresponding to the written elements. *Sweet* (31) says that the only breaks made in language are those made by the breath pauses which have a close relation to the logical units of our language. *Wallin* (36) has called attention to the fact that the average num-

ber of syllables between these breath-pauses is only about six. *Scripture* (28) also has called attention to the fact that the utterance of any word calls into play three different sets of muscles: the muscles of the chest which control respiration; of the larynx which produce sound by making the vocal cords tense; and of the tongue, jaws, and palate which modify the sound. *C. T. Gray* (10) after studying pneumograph records of 40 children states that there are sex differences in breathing during oral reading and that there are decided differences for the various school grades.

Since there appear to be no investigations applying directly to the subject of our investigation, the most significant studies with which direct comparison can be made are those pertaining to dysintegrations in overt speech and reading. Although no studies have been made of eye-movements as such during stuttering, very careful investigations have been made of stutterers' breathing during overt speech and reading. As has been stated previously the special concern of this experiment is whether the dysintegrations of overt speaking and reading in stutterers are sufficiently deep-seated to be significantly manifested in silent reading and reasoning. The findings pertaining to the outer or explicit activities are suggestive as to the factors which may or may not be found in regard to the more inner and implicit activities.

Fossler (8) has reviewed most of the work on record concerning the breathing of stutterers during overt speech, reporting the results of *Halle* (16), *Ten Cate* (32), *Gutzmann* (15), *Robbins* (26), and *Fletcher* (7). Of special concern in this study is the work of *Travis* (34) who found the following dysintegrations at various times in the motor speech units during stuttering: (1) a complete antagonism between the action of the thorax and that of the abdomen; (2) a marked synchronism between the movements of the larynx and those of various units of the breathing apparatus; (3) a marked prolongation of inspiration; (4) clonic and tonic spasms of the various muscles of speech production; and (5) the apparent introduction of a new tremor rate in the abdomen.

Fossler (8) made a statistical and descriptive study of the breathing curves of 13 stutterers. He concluded: (1) that there are some observable, typical, recurrent patterns which are not, however, definitely associated with the attempt to produce any particular sound or group of sounds. They are, in this sense, general and not specific patterns. A few patterns have been found characteristic of several individuals while a few have been found characteristic of only one individual. (2) The study of variability showed that there was no significant difference between stutterers and normals with reference to amplitude of inspiration and expiration. Stutterers were found to be 52 per cent more variable than normals in the time of inspiration and 46 per cent more variable than normals in the time of expiration. Speech breathing was approximately three times more variable than rest breathing for both stutterers and normals. The average length of the full-breath interval during speech was greater than for rest breathing in both stutterers and normals, the gain being 14.6 per cent for stutterers and 7.3 per cent for normals. (3) The descriptive study of curve forms showed that stutterers present from two to five times more anomalous curves than normals, although in the remaining curves the rank order of frequency was comparable to that of normals. Stutterers showed approximately twice as many expirations that were interrupted by inspirations as normals and the frequency of such interruptions within the expiration was greater. Stuttering may have been accompanied by tonic and clonic spasms in the breathing and laryngeal apparatus, by temporal opposition of the breathing curves, by attempts to speak on inspiration, by greatly prolonged expiration, and by a breaking up of the normal rhythm of speech.

The great variety of circumstances and the lack of uniformity of conditions under which stuttering is set up with all these consequent and various dysintegrations was indicated by *Bryngelson's* study (1) of articulatory difficulties in 13 stutterers. His conclusions were: (1) Ten per cent of the cases had difficulty with medials or sounds other than the initials of the word. (2) Stutterers had difficulty with both consonants and vowels. (3) Stuttering occurred in both social and non-social situations.

(4) There was marked inconsistency as to when, on what sound, and how stuttering occurred. (5) All subjects did not have equal trouble with the same sounds. The number of difficulties varied from person to person and from time to time. (6) Stuttering occurred on both initial vowels and consonants. (7) It seemed impossible to arrange the sounds of the alphabet in any kind of order from the standpoint of effectiveness in producing stuttering. (8) There was no consistency in the repetitions. Words, phrases, syllables, or sounds were repeated. They varied from person to person and from time to time. (9) The speech organs of stutterers functioned as normally as those of normals except when stuttering was in progress. (10) Substitutions showed the same inconsistency as repetitions.

The general breathing capacity and habits of stutterers were studied by *Starr* (30) who found that about 80 per cent of the stammerers who applied at the University of Pennsylvania Speech Clinic for treatment were sub-breathers and had characteristically high arterial carbon dioxide partial pressure. *Trumper* (35) found that practically one-half of 82 adult stammerers in 101 cases studied had lowered vital capacities, which were compensated by (1) normal breathing accompanied by periodic deep breaths, or (2) rapid shallow breathing, or (3) a definite increase in the volume per breath. Depth of breathing was found to be inversely proportional to the degree to which vital capacity was below normal. *Trumper* further explained that in all three groups of stutterers, namely, those having low, normal and high vital capacity, from 15 to 50 per cent were shallow breathers.

The above survey covers the extent of the work on breathing relevant to our study. It will be noted that this research has been confined to the breathing during normal speech, by non-stutterers during "mental" work, during oral reading by non-stutterers, and during speech and oral reading by stutterers. We have not been able to find any reports of studies of breathing in stutterers during silent reading and reasoning.

Somewhat the same situation is true in the field of eye-movements. While a number of studies have been made relevant to eye-movements during both silent and oral reading and of both

good and poor readers, no records appear of any investigations relating specifically to stutterers. But, as with the breathing movements, in order to have standards of comparison with the results from our study upon stutterers, it is worth while to review the findings pertaining to non-stutterers in silent and oral reading and for efficient and inefficient readers.

Of the 435 scientific studies of reading which *W. S. Gray* (13) enumerates as having been made between the years of 1884–1924 a rather large number have had some bearing upon the evolution of experimental technic that has been devised for the study of eye-movements. *Schmidt* (27) related the progressive improvements for the study of eye-movements from the early use of mirrors, observation of after-images, use of telescopes, microphones attached to the eyelids, plaster-of-Paris cups attached to the corneas of the eyes, to the present methods of photographing beams of light reflected from the corneas upon moving films. *Volkmann* and *Lamansky; Javal, Lamore,* and *Landolt* of Paris; *Erdmann* and *Dodge* at Halle; *Delabarre* at Harvard; *Huey* at Clark; *Dodge* at Wesleyan; and *Dearborn* at Columbia were outstanding pioneers in the work. Much of the recent work has been centered at the University of Chicago by *Freeman, Judd, C. T. Gray, Buswell,* and *W. S. Gray.*

Tinker (33) after an analysis of a number of studies in eye-movements indicated that photographic records yield five measures of reading performance; namely, (1) duration and extent of eye-movements, (2) number of pauses per line, (3) number of regressions per line, (4) pause duration, (5) perception time per line. In regard to the effectiveness of these different measures he concluded: (1) that perception time per line was the most valid photographic measures of speed of reading; (2) in reading easy narrative, pause frequency was a very good measure, pause duration a good measure, and regressive frequency a fair measure of reading performance; (3) in scientific prose (study attitude) pause frequency was a very good measure, regression frequency a good measure, and pause duration a fair measure of reading performance; (4) only a moderate-sized correlation (about .46) existed between performance in reading easy narra-

tive and in reading scientific prose (study attitude). *L. C. Pressey* (25) in an experiment with 56 good readers who were paired against 56 poor readers found the following specific elements making for proficiency in reading when intelligence was constant: (1) the good reader had fewer fixations; (2) he had fewer regressive movements; (3) he hit the beginning of the line accurately; (4) he had much less vocalization than the poor reader; (5) the good reader could increase his vocabulary, because he knew how sounds were put together and he could take words to pieces into their constituent sounds. Because of this ability he could build up his vocabulary and could thereby get the meaning of what he read. It is due to this characteristic, along with good eye-movements, that the good reader had a high degree of comprehension.

Of particular interest for this study are the findings to the effect that good reading showed regularity, uniformity, and rhythm of movements. *Huey* early observed the fact that "readers showed a strong rhythmic tendency. Each would fall into a reading pace that seemed most natural to him and would then read page after page in almost exactly the same time" (17). *Dearborn* (5) supports the same view, when he said, "It is, in the writer's belief, clearly indicated by the above experiments that one of the essentials of natural and rapid reading is that the reader's eye should at once be able to acquire a regular and uniform motor habit of reaction for each line." In summarizing the results of a comparative study of the habits of mature and immature readers, *Buswell* (2) pointed out: "In the eye-movement record of a mature reader it will be seen that the eye progresses across the lines in a rhythmic swing, making approximately the same number of fixations per line, with few or no backward movements. In contrast with this the immature reader moves forward a few fixations, then backward to refixate upon some word which is not clearly recognized, then forward, and soon back again in the reverse direction. This oscillation of eye-movements back and forth along the lines indicates that the reader is confused and is unable to proceed in regular order along the lines." *C. T. Gray* (11), after analyzing *Buswell's* data.

stated: "It is clear from these data that the development of rhythm is almost a continuous process. . . . If this point of view is correct, the final perfection of the reading habit is to be attained through the development of rhythm and not through those devices which make for a longer active span of perception or for a shorter reaction time." *W. S. Gray* (13), after reviewing various studies, said that: "It is clear that rhythmical progress of perceptions characterizes the good reader and is one of the desirable goals of reading instruction."

Reduced to terms of integration and dysintegration it is evident that there is integration of eye-movements when there are rapid, regular, and approximately rhythmical movements along each line with accurate rapid return sweeps between them. Dysintegration approaches as the number of regressions variously increases, or the length of duration of pauses becomes unduly long, or the deviation in the length of pauses increases, or as there is an increase in inaccuracy of the return sweeps in hitting at the beginning of the lines. Generally speaking, it may be said that efficiency in reading corresponds to the amount of integration.

Duration of fixations, number of fixations per line, and number of regressive movements per line have been investigated by *Huey* (18), *Javal* (20), *Landolt* (22), *Dodge* (6), *Erdmann* (summarized in 23), *Dearborn* (4), *Schmidt* (27), *C. T. Gray* (12), *Buswell* (2), and others. A part of the conclusions obtained are presented at a later point in this study. (See Part III, Comparisons With Other Studies.)

Tinker (33) studied eye-movements in relation to reading matter of four different degrees of difficulty, and found that on the average about 94 per cent of the reading time was utilized by the pauses, leaving only about 6 per cent to be consumed by the actual eye-movements. He further found that the relation between eye-movement duration and reading time bore a constant relationship to the reading attitude. It was found that the more careful and analytical the reading the smaller this ratio. When the mental processes involved in the reading were more complex the reading pauses consumed a relatively greater per cent of the total time. Thus it is apparent that the period of significant

stimulation is limited to the durations occupied by the fixation pauses.

Buswell (2) discovered four types of regressive movements: (1) "The most common regressive movement occurs at the beginning of a line where the return sweep of the eye has failed to carry the fixation back to the first word in the line and an additional regressive movement is required to make the initial part of the line clear. This type of regressive movement persists up to the more mature stages of reading." (2) A second type of regressive movement is caused by the fact that mature readers read with a relatively small number of fixations. "In their effort to grasp a larger unit in a single eye-fixation they occasionally overreach their maximum span and find it necessary to make a backward eye-movement to clarify the meaning. However, the most mature readers have overcome this tendency and make few if any regressive movements." (3) Lack of knowledge is a third cause of regressive movements. These occur among both children and adults when word difficulties are encountered. (4) A fourth type of regressive movement is characterized by a "random oscillation of the eye with no apparent plan on the part of the reader. . . . The reader fails to get a clear perception of the meaning and accordingly sets up a series of eye-fixations which move back and forth over the area, causing difficulty. This type of eye-movement may occur in the beginning stages of reading, where it shows lack of ability to grasp proper units of recognition, and it may occur in the later stages of reading where the reading gives way to analysis of some kind."

The content of different types of reading matter may also influence the number and kind of regressive movements. *Judd* and *Buswell* (21) photographed the eye-movements of several subjects when reading fiction, geography, rhetoric, easy verse, French grammar, blank verse, and algebra. Their records show that a reader may make many more regressive movements in reading some types of material than in reading other types. Likewise *C. T. Gray* (12) found that the number of regressive movements varied with different types of material, such as prose

and poetry. The number of regressive movements may also be increased by changes in the purpose of reading. *Judd* and *Buswell* (21) found that the average number of regressive movements was usually greater in study than in rapid reading.

III. Methods and technique in quantitative study of breathing movements of stutterers during silent reading and reasoning. The purpose of this part of the experiment was to ascertain in quantitative terms the relative variability of the breathing of stutterers as compared with non-stutterers during silent reading and reasoning. All phases of the breathing process were measured, namely, amplitude of inspiration, duration of inspiration, amplitude of expiration, duration of expiration.

The *O*s of the investigation consisted of 18 of the stutterers who were patients at the Speech Clinic of the University of Iowa, and 18 non-stutterers from the University of Iowa and the public schools of Iowa City. In order to control as many of the factors of the experiment as possible and to obtain data from the normal group that could be validly compared with the data from the group of stutterers it was decided to pair each stutterer of the age of 19 or below with a non-stutterer who had an approximately equivalent age, grade, and intelligence quotient. All other stutterers were considered sufficiently mature to require that they be paired only according to their I.Q., but the comparison by age was also made as far as convenient. In all of the cases except one, each stutterer was also paired with a non-stutterer of the same sex.

The following were the steps involved in this part of the experiment: (1) assembling of reading and reasoning materials suitable in difficulty to the educational age of the *O*s; (2) operating the kymograph with pneumographs and other apparatus for each stutterer and each normal *O* while he read silently and reasoned; (3) measuring and recording of amplitude of inspirations and expirations and the duration of inspirations and expirations as represented by the breath curves; (4) calculating from the resulting data the averages in standard deviation and coefficient of variation for amplitude of inspiration, amplitude of expiration, duration of inspiration, and duration of expiration, for the dif-

ferent types of reading and reasoning; (5) making of tabulations, comparisons, and conclusions.

Two factors were considered in. assembling the reading and reasoning materials for the breathing tests and the reading materials for the eye-movement tests: (1) the reading must be neither too easy nor too difficult for the *O*s concerned in order that their typical and normal reactions may most surely be brought into play throughout the tests; and (2) sufficient samples from the varying types of literature and reasoning must be utilized in order to bring into play as adequately as possible the whole range of the individuals' reading and reasoning reactions.

Because seven of the stutterers were college graduates, three were college students, seven were high school students, and one a girl in the fourth grade, *E* decided to utilize materials of three main levels of difficulty; that is (1) materials suitable for use with *O*s from grades eight to the junior year in high school; (2) materials suitable from the senior year in high school to the sophomore year in college; and (3) materials commonly of the type used from the junior year in college to the graduate years in college. All the stutterers fell within the range of these three levels except the one girl in the fourth grade. For her special materials were provided from text-books used in the fourth grade.

For each level three types of literature were provided: (1) social science, (2) poetry, (3) light prose, or narrative. Social science and poetry were selected with the purpose of its having sufficient difficulty to require the individual to exercise himself in comprehending it, to call into play his characteristic work habits of study and concentration. The light prose was selected with the aim of fitting it to the individuals' level of recreational reading, having it easy enough to permit relaxation, but difficult enough to be interesting.

A selection from a tenth grade civics, another from *The Vision of Sir Launfal,* by *Lowell,* and part of a story from a ninth grade reader provided the selections in social science, poetry, and light prose, respectively, for the eighth to eleventh grade level. A selection from *Muzzey's* History, another from *The Kubla Khan,* by Coleridge, and a part of an editorial in the *Des Moines*

Register provided the reading for those from the senior grade in high school to the sophomore year in college. Selections from *Stratton's International Attitudes, Pope's Essay on Man,* and an article in *Harper's, Concerning Mr. Hoover,* by *Walter Lippmann,* provided the reading for the mature level.

In the field of reasoning each *O* was given five problems in mental multiplication, five in subtraction, five in division, two special problems, and five highly debatable propositions. He was to solve silently and as quickly as possible the mental arithmetic problems. He was to formulate as quickly as possible two reasons for the beliefs he held in regard to each of the propositions. Problems and propositions were arranged, like the reading selections, in different levels of difficulty.

The apparatus used in this part of the experiment consisted of a large-sized kymograph of standard design, four Jacquet tambours, three Sumner pneumographs with connecting rubber tubes, and one Jacquet chronometer. The kymograph's larger drum is 9½ in. in diameter and 12½ in. high. The smaller drum may be adjusted on a sliding table to take a length of paper up to 2.75 meters. A small motor especially constructed to maintain a uniform speed operates the drums at a rate which requires 7½ min. to run a full length of paper. Because the machine admitted the use of the large sized kymograph paper it was found possible and advisable to make the breathing records of 15 min. duration by making half of the record on the lower half of the paper for an entire length and half on the upper part for an entire length.

Preliminary to giving the breathing tests it was necessary to arrange the assembled reading and reasoning materials in a form in which they could be rapidly and efficiently administered once the pneumographs were placed on the subject and connected with the kymograph. Taking into consideration that it would be possible to make a breathing record representing 15 min. of reading and reasoning, the materials were therefore laid out in the following sequence for presentation: 2 min. to read social science, 2 min. for poetry, 2 min. for light prose, 1 min. for multiplication, 1 min. for subtraction, 1 min. for division problems, 1 min. for special problems and 3 min. for reasoning on propositions. This

left time of 1 min. for rest breathing which was placed at the beginning of the test and along with the 6 min. of reading occupied just one-half of the record, leaving the problems and propositions for the other half. After a number of trials it was found that the operating time allotted to reasoning permitted the solving of about five problems each of multiplication, subtraction, division, and two to four special problems, with the working out of five propositions of sufficient difficulty to require careful "concentration".

A cardboard, upon which was pasted the three selections of reading in such a way that they could be easily held by *O* and the pages quickly turned, was provided for each of the three age levels. On each card the social science selection was arranged to be read first, the poetry came second, while the light prose was last. Upon a fourth card, for the use of *E*, were placed detailed and complete directions as to every step of the procedure from the time the instruments were placed upon *O* to the finish of the breathing test. This included not only the directions for adjusting the pneumographs and operating the kymograph, but also the instructions which *E* was to give *O* between the various parts of the reading and reasoning experiment. It also included at the proper time and sequence the problems and propositions which the experimenter was to give the subject to work out mentally.

Breathing records were taken from three parts of *O*'s breathing apparatus. One pneumograph was placed in the middle of the chest at the level of the armpits; another pneumograph was placed on the lower chest just below the lower end of the sternum; and the third pneumograph was placed over the umbilicus to record abdominal changes.

Before any measures were taken from the breathing records, it was necessary to project through the high point and also the low point on each breath curve the arcs through which the stylus traveled in making the record. This was essential in order to compensate for the curvature of the stylus as it described its up and down strokes. Since duration of inspiration and duration of expiration were to be measured only by the movement to the left which the record made while a particular breath-period was on,

its duration could not be accurately measured unless these measurements were from the same point of reference as they were made, that is, according to the arc which was determined by the radius or the length of the stylus which made the record. By measuring the time of inspiration and expiration from arc to arc as they were drawn through the high and low points respectively of the breath curves a true representation of the elapsed time was obtained. This method of measurement is the same as that used by *Fossler* (7) and is explained in detail in his study. Each measurement of time was taken to the nearest ½ mm. which represented approximately $^1/_{12}$ sec. in duration.

The amplitude of inspiration was measured from the highest point at the beginning of a downward stroke to the lowest point at the end of the stroke. The amplitude of the following expiration was measured from this same lowest point, or beginning of the expiration to the highest point, or end, of the expiration. The highest points may thus be considered either as beginnings of inspirations or as ends of expirations, depending upon which measurement is desired. In the same way, the lowest points may be considered as ends of inspirations or beginnings of expirations. Both of these measures of amplitude were taken from points read to the nearest .5 mm. on a line perpendicular to the base line made by the time-marker and running through either the extreme high or low points of the curves.

All these measurements were taken from the curves made by the lower chest pneumograph since it generally recorded more minute changes than either of the other two pneumographs. Because usually approximate synchronization obtained between the movements of the three sets of curves the same set of relations held with respect to all of them.

There was an average of about 240 full breath-periods measured for each *O*. About 135 of these represented the silent reading, around 75 or 80 were for the reasoning, and the remainder were for the rest-breathing.

As was pointed out in a foregoing section, dysintegration may be considered as increasing along with an increase in variability and a consequent breaking down of the rhythm of movement.

Three statistical measures were used in determining variability: a measure of central tendency (arithmetical mean), a measure of dispersion (standard deviation) and a coefficient of variation (Pearson $V = \frac{100 \text{ S.D.}}{\text{Ave.}}$). Since all coefficients of variation are comparable with one another this measure makes it possible to compare one individual with another and one group with another. And as *Fossler* (7) has pointed out, the results obtained by the use of this coefficient will be comparable also with the results obtained from other instruments, since the relative and not the absolute measures are involved. Also it can be seen that such a coefficient is especially valuable in a study such as the present one wherein, unavoidably, there are slight variations in length of stylus levers, sensitiveness of tambours and pneumographs, chest expansion, girth and depth of breathing. In fact it would be impossible to make a valid comparison of absolute measures.

IV. Results of quantitative study of breathing movements of stutterers during silent reading and reasoning. Limitations of space permit the display of only a small number of the tables embodying the results of the breathing tests. In all the following tables the abbreviations A.M., S.D., and C.V., stand for arithmetic mean, standard deviation, and coefficient of variation, respectively.

1. Table I shows a 225.1 per cent greater C.V. in amplitude of inspiration during silent reading of social science for stutterers than for normals. The A.M. was 7.5 per cent larger for stutterers.
2. Table II summarizes all amplitudes of inspiration. Stutterers had 138.1 per cent greater C.V. than normals. The difference in A.M. was only 1.3 per cent larger than it was for the stutterers.
3. Table III summarizes all durations of inspiration. Stutterers had a greater C.V. by 56.2 per cent. The stutterers had 1.9 per cent more in A.M.
4. All amplitudes of expiration are averaged in Table IV. The stutterers had the larger C.V. by 107 per cent. The normals were greater in A.M. by 2.9 per cent.

TABLE I. *Comparison between stutterers and normals with reference to the A.M., S.D., and C.V. in amplitude of inspiration during silent reading of social science*

	Stutterers				Normals		
	A.M.	S.D.	C.V.		A.M.	S.D.	C.V.
Tay	11.0	3.21	29.18	Nic	7.45	1.02	13.69
Joh	8.8	1.14	12.95	Hen	9.06	.18	7.45
Cot	8.7	1.59	18.27	Rem	6.98	1.32	18.99
Car	10.06	4.12	40.99	Wil	7.91	.27	3.63
Cas	12.57	.31	2.48	For	9.30	.30	3.22
Maa	7.8	.27	3.51	Wat	15.3	1.21	7.94
Gri	8.5	1.43	16.82	Fla	6.20	.20	3.20
Ban	10.3	2.71	26.31	Bet	10.5	.23	2.28
Bul	12.58	4.32	34.34	Reg	5.50	.19	3.61
Ros	16.27	2.60	15.98	Rob	17.70	1.33	7.55
Rie	4.2	1.28	30.48	Wal	6.00	.27	4.61
Gus	12.	1.80	15.01	Bec	23.3	2.48	10.64
Pow	8.2	1.88	23.00	Dev	6.50	.22	3.52
Fis	6.0	.23	3.88	Rup	4.80	.19	4.02
Dow	10.71	3.32	31.10	Sta	5.30	.15	2.90
Mck	10.71	6.32	59.13	Con	8.60	.19	2.37
Vau	7.9	2.56	36.72	Har	6.90	.31	4.52
Ste	15.06	4.58	30.41	Bog	10.02	2.33	23.33
Ave.	10.02	2.42	23.91		9.29	.68	7.35

TABLE II. *Summary—Comparison of all averages of amplitude of inspiration*

	Stutterers			Normals		
	A.M.	S.D.	C.V.	A.M.	S.D.	C.V.
Social science	10.02	2.42	23.91	9.29	.68	7.35
Poetry	10.02	2.30	21.48	9.69	.95	9.00
Light prose	11.16	2.39	22.10	10.07	.92	11.76
Mental arithmetic	8.78	2.45	27.39	9.03	1.06	10.54
Propositional reasoning	9.01	2.42	28.28	10.24	1.40	14.84
Grand ave.	9.79	2.29	24.61	9.66	1.00	10.29

TABLE III. *Summary—Comparison of all averages of duration of inspiration*

	Stutterers			Normals		
	A.M.	S.D.	C.V.	A.M.	S.D.	C.V.
Social science	7.95	2.09	24.96	8.92	1.65	15.10
Poetry	11.85	2.05	23.64	8.87	1.55	15.92
Light prose	8.13	2.02	22.84	8.84	1.65	16.63
Mental arithmetic	6.43	2.48	34.38	6.89	1.80	23.61
Propositional reasoning	8.01	3.10	33.01	8.03	1.85	21.87
Grand ave.	8.47	2.34	28.16	8.31	1.10	18.02

TABLE IV. *Summary—Comparison of all averages of amplitude of expiration*

	Stutterers			Normals		
	A.M.	S.D.	C.V.	A.M.	S.D.	C.V.
Social science	10.10	2.05	25.08	9.40	1.02	9.31
Poetry	9.75	2.08	21.59	9.81	.93	9.85
Light prose	9.59	2.58	23.67	10.19	.80	7.30
Mental arithmetic	8.54	2.19	24.71	8.88	1.39	16.36
Propositional reasoning	8.49	2.14	23.43	9.55	1.23	14.41
Grand ave.	9.29	2.20	23.69	9.56	1.07	11.44

5. The average of all durations of expiration are in Table V. The stutterers had the greater C.V. by 50.8 per cent. The stutterers had an A.M. 4.3 per cent greater.

TABLE V. *Summary—Comparison of all averages of duration of expiration*

	Stutterers			Normals		
	A.M.	S.D.	C.V.	A.M.	S.D.	C.V.
Social science	9.68	1.99	20.42	8.81	1.42	14.23
Poetry	10.10	3.37	26.32	9.24	1.42	15.04
Light prose	9.89	2.42	22.28	9.11	1.50	14.76
Mental arithmetic	8.00	4.26	38.04	9.30	2.62	28.25
Propositional reasoning	10.46	3.97	31.86	9.64	2.05	19.79
Grand ave.	9.60	3.20	27.78	9.20	1.80	18.41

6. Table VI summarizes rest-breathing as compared with breathing during silent reading and reasoning.

TABLE VI. *Comparison between rest-breathing and breathing during silent reading and reasoning*

	Breathing during reading and reasoning			Rest-breathing		
	A.M.	S.D.	C.V.	A.M.	S.D.	C.V.
Stutterers						
Amplitude of inspiration	9.79	2.29	24.61	11.24	1.92	19.90
Duration of inspiration	8.47	2.34	28.16	9.69	1.94	20.88
Amplitude of expiration	9.29	2.20	23.69	11.54	2.20	20.71
Duration of expiration	9.60	3.20	27.78	11.82	2.39	20.05
Normals						
Amplitude of inspiration	9.66	1.00	10.29	9.94	1.93	17.71
Duration of inspiration	8.31	1.10	18.02	10.11	1.84	18.81
Amplitude of expiration	9.56	1.07	11.44	11.12	1.71	16.53
Duration of expiration	9.20	1.80	18.41	10.61	1.94	18.13

a. The A.M. in stutterers for the amplitude of inspiration of breathing for silent reading and reasoning was 12.9 per cent less than for the rest-breathing. In normals this difference was only 2.2 per cent.

b. The C.V. for the amplitude of inspiration in stutterers during breathing while reading and reasoning was 24.6 per cent greater than for rest-breathing. The reverse was true with normals, for whom the C.V. of amplitude of inspiration while reading and reasoning was 66.4 per cent less than during rest-breathing.

c. For stutterers the A.M. of rest-breathing for duration of inspiration was 14.4 per cent greater than during reading and reasoning, while for normals it was 17.8 per cent greater.

d. The C.V. of rest-breathing in stutterers for time of inspiration was 34.9 per cent less than the C.V. for breathing during reading and reasoning. For normals the C.V. of rest-breathing was 4.1 per cent greater than for the breathing during reading and reasoning.

e. The A.M. of rest-breathing in stutterers for amplitude of expiration was 24.2 per cent greater than for the breathing during silent reading and reasoning. For normals the A.M. was 14 per cent greater for the rest-breathing.

f. The C.V. of rest-breathing in stutterers was 17.5 per cent less for amplitude of expiration than for breathing during reading and reasoning. For normals the C.V. was 30.7 per cent greater during rest-breathing.

g. The A.M. of rest-breathing of duration of expiration was 18.7 per cent greater than the breathing for reading and reasoning. For normals the A.M. was 13.28 per cent greater during the rest-breathing.

h. The C.V of duration of expiration of breathing while reading and reasoning was 38.5 per cent greater than for the rest-breathing in stutterers. In normals it was 1.1 per cent greater.

7. Table VII summarizes all C.V.'s of the breathing of stutterers as compared with normals.

TABLE VII. *Summary—Comparison between stutterers and normals of all averages of C.V.'s in breathing*

	Amplitude of inspiration	Duration of inspiration	Amplitude of expiration	Duration of expiration
Stutterers				
Social science	23.91	24.96	28.08	20.42
Poetry	21.48	23.64	21.59	26.32
Light prose	22.10	22.84	23.67	22.28
Arithmetic	27.39	34.38	24.71	38.04
Propositions	28.28	35.01	23.43	31.86
Grand average	24.63	28.16	24.29	27.76
Rest-breathing	19.90	20.88	20.71	20.05
Normals				
Social science	7.35	15.10	9.31	14.23
Poetry	9.00	15.92	9.85	15.04
Light prose	11.76	16.63	7.30	14.76
Arithmetic	10.54	23.61	16.36	28.25
Propositions	14.84	21.87	14.41	19.79
Grand average	10.69	18.62	11.44	18.41
Rest-breathing	17.71	18.81	16.53	18.13

a. The stutterers had 121.0 per cent larger C.V. in all average amplitude of inspiration for silent reading and reasoning.

b. For all average durations of inspiration during silent reading and reasoning the stutterers had 51.2 per cent more C.V. than the normals.

c. In all averages of amplitudes of expiration, stutterers were 112.3 per cent larger in C.V. than the normals.

d. In all averages for durations of expirations, stutterers had 51.5 per cent greater C.V. than normals.

e. In relation to rest-breathing stutterers were 23.7 per cent more variable for amplitude of inspiration during silent reading and reasoning. In relation to rest-breathing normals were 39.6 per cent less variable in amplitude of inspiration during the reading and reasoning.

f. In relation to rest-breathing the breathing of stutterers in duration of inspiration during reading and reasoning was 34.8 per cent greater in C.V. This difference in normals was negligible, only 0.4 per cent less variable during silent reading and reasoning than for rest-breathing.

g. For stutterers the C.V. of amplitude of expiration during reading and reasoning was 16.8 per cent greater than that of the amplitude of expiration in rest-breathing. The reverse is true with the normals. The C.V. was 30.7 per cent less during reading and reasoning than for the rest-breathing.

h. For stutterers the C.V. of duration of expiration was 38.4 per cent larger during reading and reasoning than that of duration of expiration during rest-breathing. For normals the difference was very slight, the C.V. was only 1.4 per cent greater during reading and reasoning than for the rest-breathing.

8. Table VIII compares the breathing in C.V. of stutterers and normals during silent reading and reasoning with the breathing of stutterers and normals during overt propositional speech as studied by *Fossler* (8). (See footnote to table.)

a. The C.V. for amplitude of inspiration of our stutterers while reading silently and reasoning was 68.26 per cent of the C.V. of the amplitude of inspiration of *Fossler's* stutterers in overt speech. The C.V. of the amplitude of inspiration for our

normals during silent reading and reasoning was 30.31 per cent of the C.V. of the amplitude of inspiration for *Fossler's* normals in overt speech. It was 69.85 per cent as great for our stutterers while reading silently and reasoning as it was for *Fossler's* normals while speaking overtly.

TABLE VIII.[1] *Comparison of C.V.'s of breathing during silent reading and reasoning with the C.V.'s of breathing during overt propositional speech as studied by* Fossler (7)

	Breathing for silent reading and reasoning in		*Fossler's* results for breathing in overt speech in	
	Stutterers	Normals	Stutterers	Normals
Amplitude of inspiration....	24.63	10.69	36.08	35.26
Duration of inspiration.....	28.16	18.62	41.55	32.12
Amplitude of expiration....	24.19	11.44	37.05	35.20
Duration of expiration.....	27.76	18.41	51.1	40.2

b. The C.V. of duration of inspiration for stutterers while reading silently and reasoning was 67.77 per cent as large as the C.V. of the duration of inspiration for *Fossler's* stutterers while in overt speech. For stutterers while reading silently and reasoning it was 87.67 per cent as great as that for *Fossler's* normals while speaking.

c. The C.V. of amplitude of expiration of stutterers while reading silently and reasoning was 54.32 per cent of the C.V. of amplitude of expiration of *Fossler's* stutterers while speaking overtly. For our normals during silent reading and reasoning it was 32.50 per cent of that for *Fossler's* normals in overt speech. For our stutterers while reading silently and reasoning it was 68.72 per cent of that for *Fossler's* normals while speaking overtly.

d. The C.V. of duration of expiration of our stutterers while reading silently and reasoning was 54.32 per cent of that for *Fossler's* stutterers in overt speech. For our normals during silent reading and reasoning it was 45.79 per cent of that for

[1] In interpreting this table it should be borne in mind that *Fossler's* 13 stutterers were more mature as a group than those in this study. All of his *O*s except two were above high school level, while all of his normals were graduate students. Inspection of the records of the various *O*s will show an increasing C.V. with decrease in age. This fact calls for much care in making exact comparisons between the two groups. However, the comparison should be valid for practical purposes.

Fossler's normals in overt speaking. For our stutterers while reading silently and reasoning it was 69.05 per cent of that for *Fossler's* normals during overt speech.

By way of summary our records of the breathing of stutterers during silent reading and reasoning exhibit the following manifestations of dysintegration in the breathing movements:

1. Our stutterers had far-reaching variations in depth of breathing for both inspiration and expiration. In amplitude of inspiration they averaged 121.0 per cent greater in coefficient of variation than the normals. In amplitude of expiration they averaged 112.3 per cent greater in coefficient of variation than did the normals.

2. Our stutterers had abnormally large variations in duration of both inspiration and expiration. Their duration of inspiration averaged 51.2 per cent greater in coefficient of variation than the normals. Their duration of expiration averaged 51.5 per cent greater coefficient of variation than was the case with the normals.

3. While our stutterers had a greater amplitude of inspiration in both rest-breathing and breathing during silent reading and reasoning, the normals had a slightly greater amplitude of expiration. In both duration of inspiration and duration of expiration for rest-breathing as well as for breathing during silent reading and reasoning the stutterers took slightly more time. These facts do not support the work of *Trumper* (35) who stated that from 15 to 50 per cent of his stutterers were shallow breathers and that one of the ways in which compensation was made for a lower vital capacity was by means of rapid shallow breathing.

4. Taking rest-breathing as a basis of comparison, silent reading and reasoning involved a greater repression of amplitude of inspiration and expiration, and a greater duration of expiration in the stutterers than in the normals. For duration of inspiration the normals required slightly more time than did the stutterers.

5. In all phases of the breathing process stutterers exhibited approximately two-thirds as large a coefficient of variation in silent reading and reasoning as did stutterers in overt propositional speaking. In all phases of the breathing process normals exhibited about one-third as large a coefficient of variation in

silent reading and reasoning as did normals in overt propositional speaking.

6. The results of this experiment agree with those aspects of the work of *Skaggs* (29) in which comparisons can be made, namely, that a period of mental work (multiplication) produced the most shallow breathing; mental relaxation produced a greater amplitude of breathing; *O*s breathed fastest in mental work and slowest in relaxation. The findings of this experiment indicate that there is more close integration and regularity in the breathing of normals during silent reading than during rest-breathing and that irregularity increases over that of the rest-breathing slightly with the arithmetical problems and propositions (Table VII).

V. Results of qualitative study of breathing movements of stutterers during silent reading and reasoning. The questions which this part of the study attempted to answer are as follows: (1) What are the typical patterns of movements in amplitude and duration of the breathing of stutterers during silent reading and reasoning? (2) What proportion of the movements follow each of the different typical patterns ascertained? Are most of the movements confined to a relatively small number of the typical patterns, or are most of them employed with considerable frequency?

Thus far our analysis of the dysintegrations characteristic of stutterers has proceeded by a study of variability in the functioning of the breathing apparatus as revealed by the quantitative measures of standard deviation and coefficient of variation as applied to four different phases of the breathing process, namely, amplitude and duration of inspiration, and amplitude and duration of expiration. The breathing records, however, present other aspects open to direct observation, analysis and classification. And since the approach available is a qualitative one it may quite appropriately supplement the work thus far done.

Our method of analysis is a modification of that used by *Fossler* (8), who as a part of his study, made a qualitative analysis of breathing curves of stutterers during overt speech. Necessarily his analysis applied particularly to expirations, since it is only during expiration that speech, except in extreme patho-

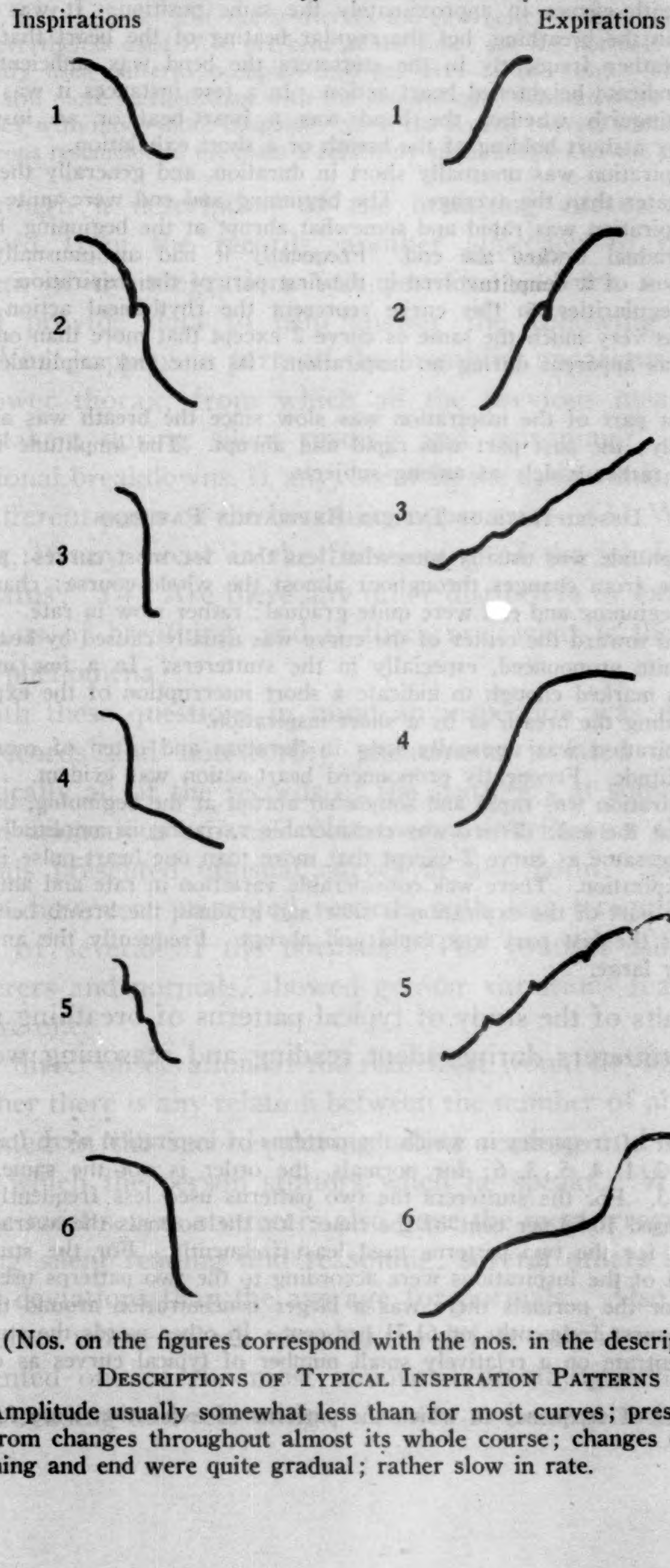
logical cases, can occur. For that purpose he confined his analysis to three parts of the expiration curve, its beginning, course and end. He was able to isolate six different typical patterns for each of these parts of the expiration and to classify the breathing during stuttering accordingly. Such an analysis, however, is not adequate for our purposes in the study of breathing curves during the implicit activities of silent reading and reasoning. These performances, it must be assumed, normally go on as well during inspiratory as during the expiratory phase of breathing and for that reason any analysis must apply to the whole breathing curve.

Inspection of the breathing curves during silent reading and reasoning of all the normals and of practically all of the stutterers revealed that the movement patterns of both inspiration and expiration could be reduced to six for each of these phases. Accordingly, six typical patterns of inspiration and of expiration were isolated. Then from the record of each *O*, stutterer and normal, were taken 100 full breath periods which were tabulated and classified. The classification of each of these waves was made in two ways, first, according to a particular one of the six typical patterns of inspiration represented, and according to a particular one of the six typical patterns of expiration represented. Of the 100 full breath periods taken, 60 were taken from the silent reading, and 40 from the reasoning parts of the record. Excluding the first wave at the beginning of each test, and all waves that indicated abnormalities from outside factors such as coughing, sighing, *etc.*, the tabulations were made from consecutive waves.

The classification of each curve was in all instances according to the one of the six typical patterns it most nearly resembled. In several cases of the stutterers a small number of the curves only remotely resembled the typical patterns with which they were classed. In both stutterers and normals certain patterns occasionally fell in between two of the typical forms or embodied the characteristics of more than one form. But in all instances the classification was made to that typical pattern most characteristic of the curve.

Table IX gives the typical amplitude and time patterns found in the study. Corresponding to each curve is its description on the following page.

TABLE IX. *Typical breath curve forms*



(Nos. on the figures correspond with the nos. in the descriptions.)

DESCRIPTIONS OF TYPICAL INSPIRATION PATTERNS

1. Amplitude usually somewhat less than for most curves; pressure even and free from changes throughout almost its whole course; changes of pressure at beginning and end were quite gradual; rather slow in rate.

2. The bend toward the center of the curve was slight and occurred on a series of breath curves in approximately the same position. It was not an irregularity in the breathing, but the regular beating of the heart that caused the bend. Rather frequently in the stutterers the bend was sufficiently pronounced to indicate heightened heart action. In a few instances it was impossible to distinguish whether the bend was a heart-beat or an inspiration interrupted by a short holding of the breath or a short exhalation.

3. The inspiration was unusually short in duration, and generally the amplitude was greater than the average. The beginning and end were quite abrupt.

4. The inspiration was rapid and somewhat abrupt at the beginning, but was slow and gradual toward the end. Frequently it had an unusually large amplitude, most of it being involved in the first part of the inspiration.

5. The irregularities on this curve represent the rhythmical action of the heart. It was very much the same as curve 2 except that more than one pulse movement was apparent during an inspiration. Its rate and amplitude varied considerably.

6. The first part of the inspiration was slow since the breath was admitted very gradually; the past part was rapid and abrupt. The amplitude for this curve varied rather widely as among subjects.

Descriptions of Typical Expiration Patterns

1. The amplitude was usually somewhat less than for most curves; pressure even and free from changes throughout almost the whole course; changes in pressure at beginning and end were quite gradual; rather slow in rate.

2. The bend toward the center of the curve was usually caused by heart-beat, sometimes quite pronounced, especially in the stutterers. In a few instances the bend was marked enough to indicate a short interruption of the expiration either by holding the breath or by a short inspiration.

3. The expiration was unusually long in duration and often of more than average amplitude. Frequently pronounced heart-action was evident.

4. The expiration was rapid and somewhat abrupt at the beginning, but slow and gradual at the end. There was considerable variation in amplitude.

5. Much the same as curve 2 except that more than one heart-pulse is noted during the expiration. There was considerable variation in rate and amplitude.

6. The first part of the expiration is slow and gradual, the breath being held in somewhat; the last part was rapid and abrupt. Frequently the amplitude was unusually large.

The results of the study of typical patterns of breathing movements in stutterers during silent reading and reasoning were as follows:

1. The order of frequency in which the patterns of inspiration were found for stutterers is 2, 1, 4, 5, 3, 6; for normals, the order is not the same, being 2, 5, 4, 1, 6, 3. For the stutterers the two patterns used less frequently were nevertheless used 10.72 per cent of the time; for the normals the average was 3.49 per cent for the two patterns used least frequently. For the stutterers, 52.27 per cent of the inspirations were according to the two patterns used most frequently; for the normals there was a larger concentration around the two patterns used most frequently, or 61.71 per cent. In other words the stutterers did not concentrate on a relatively small number of typical curves as did the normals.

2. The order of frequency in which the patterns of expiration were found in

stutterers is 5, 2, 3, 1, 4, 6; for normals, the order shows a marked difference, being 2, 5, 4, 1, 3, 6. For the stutterers the two patterns used least frequently were nevertheless used 17.16 per cent of the time; for the normals the two least frequently used patterns occupied 5.60 per cent of the time. The conclusion here is still more marked than with the inspirations; the stutterers were inclined to employ with much more frequency all of the typical curves, while the normals' expirations resembled in the main a relatively small number of the typical curves.

Through a description of the breathing curves as directly observed from the records, another approach to the general problem of dysintegrations was permitted. Such a description would provide data to help answer the following questions: (1) What happens in parts of the breathing apparatus other than the lower thorax, from which all the previous measures have been taken, during silent reading and reasoning? (2) What functional breakdowns, if any, occur in the synchronisms between the different parts of the breathing apparatus? (3) What breakdowns, if any, occur in the functioning of the whole breathing apparatus? (4) Are there any other distinctive or extraordinary reactions of breathing, and if there are, what is the nature of these phenomena?

With these questions in mind an inspection was made of all the records and noteworthy phenomena isolated and labeled. Practically all of the records of the stutterers at some point presented anomalous curves. Not over a fourth or a third of the normals presented unusual curves at any point. Several stutterers, however, presented records with less irregularities than those of several of the normals. The younger subjects, both stutterers and normals, showed greater variations than the more mature ones.

By direct observation of the records it would be difficult to say whether there is any relation between the number of abnormalities indicated in the records during silent reading and the severity with which the person stutters when he speaks. While several of the most severe stutterers also gave the most irregular records during silent reading and reasoning, several others showed few more deviations than the average for normals. Also, one of the stutterers whose speech revealed the defect only in a small degree presented one of the most abnormal breathing records during silent reading and reasoning. As was to be expected there was a

somewhat larger proportion of the more radical disturbances in the reasoning processes than in the silent reading, probably because reasoning was generally the more difficult and hence more likely to call out inadequate modes of response.

In the following figures samples only are given of the large number of mal-functionings presented in the records. They are presented as typical of the dysintegrations in breathing of stutterers during silent reading and reasoning. Almost all the different types of reasoning and reading are represented in the exhibit. In the following exhibits the upper curve of each record represents the breathing recorded by the upper pneumograph which was placed across the chest beneath the armpits; the middle curve is from the region of the diaphragm or lower thorax, while the lower curve is for the abdomen. The straight line near the bottom is the time-line upon which the seconds are indicated as the drum traveled to the left. A downward movement of the styli represents inspiration; and an upward movement of the styli indicates expiration.

Fig. 1 is a sample of the breathing of Bul during silent reading of poetry. The block is 17 sec. in duration. The unusually large amplitudes at the left followed other similar blocks throughout the reading.

Fig. 2 is a part of the breathing record of Car during the reading of social science material. It shows several abnormally rapid and deep inspirations with two blocks in the diaphragm and abdomen and near blocks or interrupted expirations in the upper chest. Tonic spasms occur with the blocks. There is one instance of a well-marked interruption of inspiration by a short expiration.

Fig. 3 is a section of the breathing record of Mck's silent reading of poetry. There are few signs of integration. Three different breathing records were made of this subject in order to make certain that the irregularities were not the result of emotional tensions incident to the experiment. This sample is typical of the disturbances throughout all three records with the exception of her rest breathing which was not especially abnormal. This record shows a prolonged block both at the beginning and the end of the period. The first block shown here lasted 13 secs. during which time there were practically no breathing movements presented by any part of the breathing mechanisms.

Fig. 4 represents the breathing of Vau while reading silently social science material. At one or another point practically all the phenomena thus far described are evident in these 27 secs. of performance. Especially pronounced are the disturbances in the lower part of the breathing mechanism with the tonic and clonic spasms, the blocks, abnormally deep and rapid inspirations and expirations and the intervals presenting interruptions. Three periods of block appear in which the entire breathing apparatus is affected to some extent.

Fig. 5 is from the breathing record of Con, a non-stutterer, while reading poetry silently. It is typical of the reading and reasoning records of all the normals except several of the younger and, incidentally, less efficient readers. Except for the fact that the amplitudes are slightly less these curves are typical

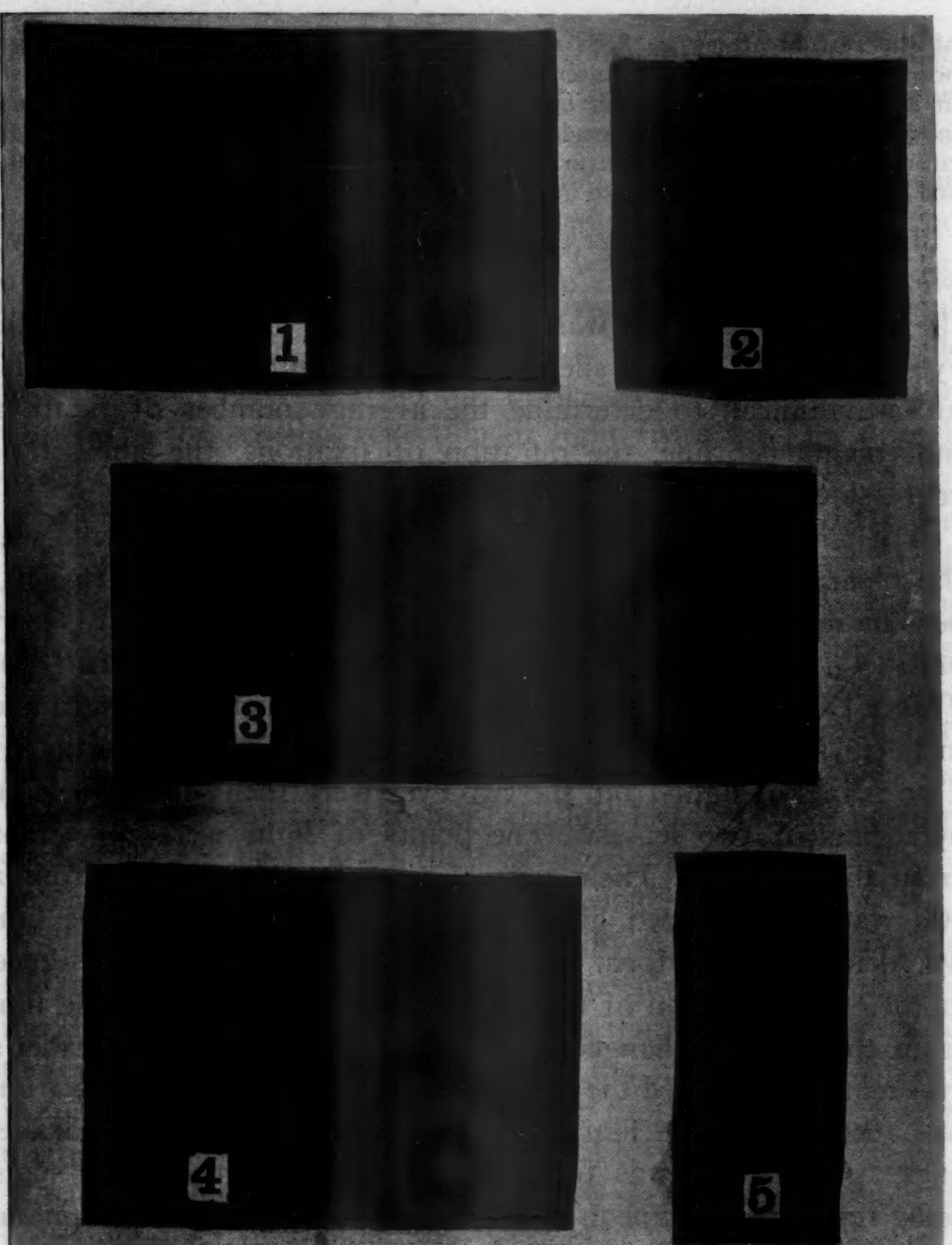


FIG. 1. Breathing records of Bul (stutterer) during silent reading of poetry. In this record and in all subsequent records of breathing reading from above downward the first curve records movements of the middle chest, the second, movements of the lower chest and the third, movements of the abdomen.

FIG. 2. Breathing records of Car (stutterer) during silent reading of social science material.

FIG. 3. Breathing records of Mck (stutterer) during silent reading of poetry.

FIG. 4. Breathing records of Vau (stutterer) during silent reading of social science material.

FIG. 5. Breathing records of Con (normal speaker) during silent reading of poetry.

of the rest breathing of both stutterers and non-stutterers. However, each normal, and most of the stutterers, presented curves that were characteristic in amplitude and in duration of the particular individual, and the breathing movements continued to be made in this characteristic manner throughout the entire record. But almost invariably the characteristic curves were less stable and more difficult to recognize in the stutterers.

VI. Methods and technique in quantitative study of eye-movements of stutterers during silent reading. In this part of the study the purpose was to find out the extent to which the eye-movements during silent reading of stutterers were regular and rhythmical, to determine the average number of fixation-movements per line, the duration of fixations, the number of regressions, and the fixation time per line.

The Iowa camera for the photography of eye-movements was the apparatus used. It is a modification of the apparatus that has become more or less standard as developed by *Dodge* (6), *Dearborn* (4), *Schmidt* (27), *C. T. Gray* (10), *Miles* and *Shen* (23), *Tinker* (33) and others. The camera was 50 inches in length and made to accommodate standard 35 mm. film running vertically. Two points of light from the two eyes were focussed on the film by means of two lenses. The points of light were reflections from the corneas. Their sources were beams of light from a 100 watt concentrated filament nitrogen filled lamp. The film was driven at a uniform rate of speed by an especially designed motor. The position of the points of light reflected on the film from the corneas changed with each movement of the reader's eyes as they traversed the lines of reading matter. Each fixation was recorded on the film as a pair of sharply focussed parallel lines. A time line was formed by a series of small black spots being registered by a neon light located in the back of the camera. By means of contacts made in an electrical circuit by connections in an electrically driven phonograph turntable the light made two flashes every second. The spots were registered at a distance apart depending upon the rate at which the film was traveling.

Three devices were used to eliminate and to furnish a check on head-movements which seemed especially prone to appear in the stutterers. A padded head-rest extended around the lower forehead from temple to temple, with a head-band arranged to fasten tightly behind the head. The head was further immobil-

ized by means of a mouth-rest over which the subject placed his upper front teeth. Both head and mouth-rest were fastened firmly to uprights and crossbars connected with a heavy table so that there would be very little vibration. A check on the head-movements, that could not be eliminated in these ways, was made by the use of a polished bead mounted between the eyes of a black mask worn by the subject. Any movement of the head would thereby be brought out by a deviation of the line on the film made by the reflection from this bead. A black mask was used to prevent the possible reflection of light from the face into the camera.

Selections from the same social science material, poetry, and light prose for the three different age levels as were used for the breathing tests were prepared for the purposes of eye-photography. Each of the nine selections were typed off in single spaces and mounted on cardboards 10.5 x 10 cm. and set up in a position directly beneath the camera lenses which were directly in front of the eyes. The length of the typewritten lines was 10 cm. Care was taken to have the left hand margins perfectly even, since the position of the first fixation on each line was of importance in studying the eye-movements.

The reading matter was illuminated by a study lamp in which the reflector was covered by a layer of deeply saturated red paper through which the light was directed on the reading cards. Since the eye-tests had shown that many of the subjects had defective vision much care was taken to adjust the light on the reading matter for each subject so that it could be seen clearly.

After the film was in place much care was required to hold the focus obtained throughout the test. One adjustment was provided so that the two lenses in front of the eyes could be separated or brought nearer together. Another adjustment allowed one lens to be raised while the other was lowered and *vice versa.* The third and fourth adjustment allowed the camera to be moved horizontally or vertically. A fifth adjustment permitted a small lengthening or shortening of the camera.

For each of the three samples of reading the stutterers were permitted to read for 40 secs., or two min. in all. For the normals

the time was set at 30 secs. for each selection or 1.5 min. as the total reading time. This length of time permitted at least 100 fixations for each type of reading.

Variability in eye-movement rhythms was indicated by a study of the average number of fixations, the average duration of fixations, the standard deviation in thousandths of a second and the coefficients of variation for the duration of fixations, and the average number of regressive movements per line. Also the perception time per line was determined.

VII. Results of quantitative study of eye-movements of stutterers during silent reading. Tables XII to XV present the data gathered from this phase of the study. In Table XIV, S.D. and C.V. represent the standard deviation and coefficient of variability, respectively.

1. Table X shows that stutterers had an average of 22.34 per cent more fixations per line for silent reading than did non-stutterers.

TABLE X. *Comparison between stutterers and normals in the average number of fixations per line*

Stutterers		Normals	
Tay	7.47	Nic	5.92
Joh	7.55	Hen	4.81
Cot	6.91	Rem	4.94
Car	6.00	Wil	6.76
Cas	6.25	For	2.28
Maa	7.24	Wat	6.90
Gri	7.70	Fla	5.66
Ban	8.80	Bet	7.08
Bul	8.65	Reg	4.95
Ros	8.50	Rob	6.00
Rie	9.83	Wal	10.88
Gus	6.39	Bec	7.00
Pow	7.25	Dev	6.14
Fis	6.50	Rup	7.00
Dow	7.17	Sta	4.86
Mck	10.23	Con	6.68
Vau	9.65	Har	6.50
Ste	8.86	Bog	7.81
Ave.	7.83	Ave.	6.40

2. Table XI indicates that stutterers averaged .81 of a regression more per line than did the non-stutterers. This was 126.5 per cent more in number of regressive movements for the stutterers.

TABLE XI. *Comparison between stutterers and normals in average number of regressions per line*

Stutterers		Normals	
Tay	1.72	Nic	1.78
Joh	1.05	Hen	.18
Cot	.50	Rem	.23
Car	.23	Wil	.64
Cas	.78	For	.42
Maa	1.45	Wat	.40
Gri	1.10	Fla	.58
Ban	1.67	Bet	.77
Bul	1.83	Reg	.19
Ros	1.83	Rob	.57
Rie	2.92	Wal	2.00
Gus	1.43	Bec	.55
Pow	1.23	Dev	.29
Fis	1.68	Rup	.75
Dow	.95	Sta	.13
Mck	1.71	Con	.81
Vau	2.45	Har	.57
Ste	1.65	Bog	1.18
Ave.	1.45	Ave.	0.64

3. Table XII indicates that the average duration of fixations for non-stutterers was 10.3 per cent longer than stutterers.

TABLE XII. *Comparison between stutterers and normals in average duration of fixations in σ*

Stutterers				Normals			
	Ave. Duration	S.D.	C.V.		Ave. Duration	S.D.	C.V.
Tay	.226	.081	35.20	Nic	.241	.071	27.75
Joh	.262	.087	33.29	Hen	.235	.031	13.25
Cot	.225	.074	33.00	Rem	.232	.042	18.33
Car	.211	.112	32.76	Wil	.248	.069	28.18
Cas	.234	.087	37.49	For	.250	.048	19.44
Maa	.256	.091	43.31	Wat	.294	.084	28.45
Gri	.210	.111	43.56	Fla	.199	.045	22.17
Ban	.255	.09	35.48	Bet	.218	.073	35.29
Bul	.206	.073	35.42	Reg	.238	.079	17.34
Ros	.298	.145	48.84	Rob	.331	.138	41.76
Rie	.218	.083	38.04	Wal	.344	.134	38.95
Gus	.195	.091	47.17	Bec	.292	.13	44.78
Pow	.219	.95	43.36	Dev	.282	.061	21.79
Fis	.202	.095	47.20	Rup	.245	.13	44.78
Dow	.262	.11	42.18	Sta	.240	.056	23.60
Mck	.288	.18	62.55	Con	.284	.12	44.56
Vau	.287	.204	72.91	Har	.241	.047	19.85
Ste	.181	.063	34.72	Bog	.218	.121	39.41
Ave.	.235	.145	42.56	Ave.	.262	.082	29.44

4. Table XII shows that the coefficient of variation of the duration of fixation was 44.52 per cent greater for the stutterers.

5. Table XIII shows that the average perception time per line was 4.09 per cent greater for the stutterers.

TABLE XIII. *Comparison between stutterers and normals in average perception time per line in silent reading*

Stutterers	Secs.	Normals	Secs.
Tay	1.88	Nic	1.42
Joh	1.97	Hen	1.13
Cot	1.55	Rem	1.14
Car	1.26	Wil	1.67
Cas	1.46	For	1.32
Maa	1.97	Wat	2.02
Gri	1.52	Fla	1.12
Ban	2.24	Bet	1.53
Bul	1.78	Reg	1.17
Ros	1.23	Rob	2.01
Rie	2.14	Wal	3.74
Gus	1.24	Bec	2.04
Pow	1.58	Dev	1.73
Fis	1.31	Rup	1.71
Dow	1.87	Sta	1.16
Mck	2.94	Con	1.89
Vau	2.76	Har	1.56
Ste	1.60	Bog	2.48
Ave.	1.78	Ave.	1.71

If the results of this study of the eye-movements of stutterers during silent reading are to be compared to any degree of reliability with the results of other studies, the comparison demands, as a very minimum, that the following factors be kept in mind: (1) length of line, (2) difficulty of reading matter, (3) maturity of the readers being compared. As explained in a previous section, the length of line used in this experiment was 10 cm.; there were three different levels in the difficulty of reading matter which permitted an adjustment to the level of maturity in the subjects; and the subjects ranged in grade level from the fourth to mature college graduates. In fact, the average grade of the subjects of this experiment was 12.1. Since none of the subjects in the studies of other investigators have been noted as stutterers by the authors, presumably, it may be assumed that they were all non-stutterers, and all our comparisons are made on that basis. There are both mature readers and immature readers, however, and both poor and good readers involved in these studies.

1. In number of fixations per line, *Buswell's* 12 high school

seniors (2) averaged 6.4 fixations per line, which was the same as the average number of fixations by the normals in this study. But since *Buswell* used the same reading matter for all his subjects in all the grades except the first, probably it was less difficult than that used in this experiment which was adapted to the grade level of the subjects. The length of the lines read by *Buswell's* subjects was 11 cm. which is less than that of the lines read by our stutterers and control group. *Buswell's* reading matter was probably a trifle more clear to the vision since it was made in regular printer's type while the subjects of this experiment read matter that had been typewritten in single space. There were probably about the same number of words read per line by both groups since *Buswell* had the words in his materials spaced unusually far apart within the lines and the size of the type he used was practically the same as the typed matter read by the stutterers.

The 7.83 fixations per line averaged by our stutterers was significantly more than 7.2 fixations per line averaged by *Buswell's* 11 high school freshmen. It was also a greater number of fixations than that made by his fourth grade, fifth grade and sixth grade subjects who averaged 7.3, 6.9 and 6.8 fixations per line respectively. *Gray's* (12) 8 high school readers had the same average number of fixations as our normals, namely, 6.4. While the lines he used were only 65 mm. in length, the print was correspondingly smaller. He used one type of reading matter for all grades. The 7.8 fixations per line by our stutterers was the same average as given by *Gray's* seventh grade subjects. *Schmidt's* adults (27) were very close to the average of our normal subjects in having 6.5 fixations per line. His lines were 90 mm. in length and his subjects read selections from *James's* " Psychology, Briefer Course ". The 7.83 fixations per line made by our stutterers compares with 7.5 made by his four high school freshmen reading descriptive passages from *Irving's* " Sketch Book ".

2. In regressive movements our normals averaged .81 of a fixation per line; *Buswell's* 12 high school seniors averaged .7 of a fixation; his 13 college students averaged .5 of a fixation. *Gray's* eight high school students had .8 of a regression;

Schmidt's four high school seniors had 1.22 regressions per line. Our stutterers with 1.45 fixations per line performed much the same as *Buswell's* 11 seventh grade subjects with 1.5 regressions per line, *Gray's* nine seventh grade subjects with 1.05, and *Schmidt's* four high school freshmen with 1.3 regressions per line.

3. In duration of fixation our normals averaged 262 σ per fixation; *Buswell's* high school seniors averaged 248; *Gray's* high school students averaged 230; *Schmidt's* high school seniors averaged 238. In comparing the stutterers' average of 235 σ as the duration of fixation it should be remembered that this average represents a much wider range of duration time than that of the normals, and as such includes many extremely long and many extremely short fixations.

4. Indirect comparisons only can be made pertaining to variability in duration of fixation. Our normals show a coefficient of variability of 29.44, and an average standard deviation of 82 σ. *Gray's* high school students had a 50 σ average variation of duration of fixation; *Schmidt's* adults had an average deviation of 78 σ per duration of fixation. Our stutterers show an average coefficient of variation of 42.56 and a standard deviation of 145 σ for duration of fixation. This is a considerably larger variation than any of the groups of non-stutterers studies by *Gray,* in which the subjects with the greatest variations in duration of fixations were his third grade students who showed 82 σ average variation in duration of fixation. The average deviation of the stutterers would not be far different from that of *Schmidt's* 21 elementary school pupils who registered 109 σ average deviation in duration of fixation.

The comparisons of average fixation time per line do not show such marked differences. Our normals averaged 1.71 sec. perception time per line. *Buswell's* high school seniors required 1.58 secs.; his college students took 1.48 secs.; *Gray's* high school students took 1.46 secs.; *Schmidt's* adult group required two secs. The perception time of our stutterers, 1.78 secs., does not indicate anything unusual in this respect.

VIII. The results of a qualitative study of eye-movements of stutterers during silent reading. In this part of the study the eye-

movement records were analyzed in an attempt to answer the following questions: (1) What are the typical patterns of movement which the eyes of stutterers present during silent reading? (2) What proportion of the movements follow each of the typical patterns ascertained? Are most of the movements confined to a relatively small number of the typical patterns or, are most or all of them employed with considerable frequency? (3) What are the typical time patterns of duration of fixations taken by the eyes of stutterers during silent reading? (4) What proportion of the movements follow each of the time patterns ascertained?

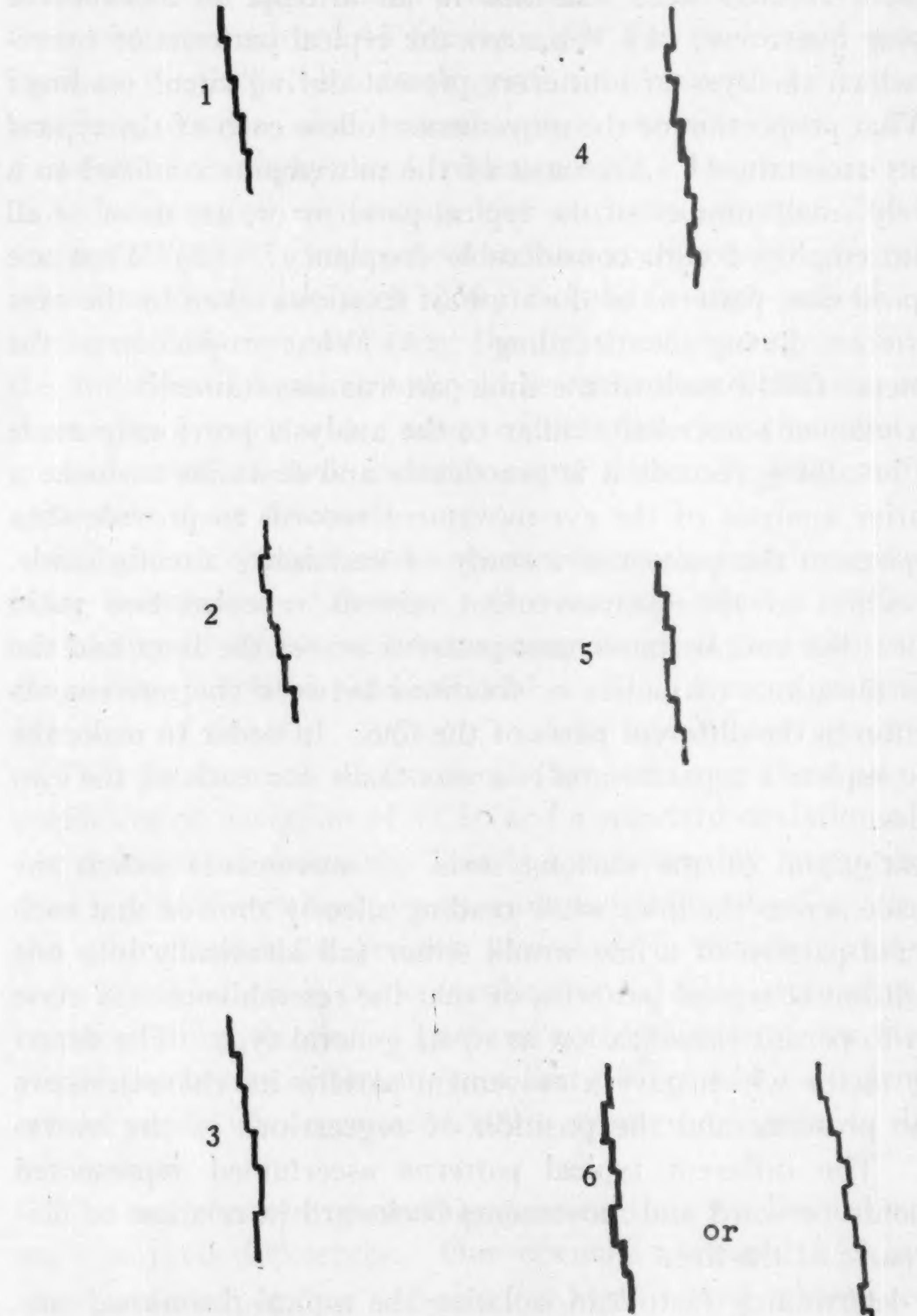
In a manner somewhat similar to the analysis previously made of the breathing records it is practicable and desirable to make a qualitative analysis of the eye-movement records to provide data to supplement the quantitative study of variability already made.

Inspection of the eye-movement records revealed two main variables: the various movement-patterns across the lines and the various durations of pauses or fixations between the movements in relation to the different parts of the line. In order to make the study complete a separate analysis was made for each of the two variables.

Investigation of the various sorts of movements which the eyes made across the lines while reading silently showed that each movement-pattern of a line would either fall identically into one of six different typical patterns, or that the resemblance was close enough to permit classification as to its general type. The determining factor which gave a movement-pattern its characteristics was the presence and the position of regressions in the movements. The different typical patterns ascertained represented movements forward and movements backward in relation to different parts of the line.

The determining factors in isolating the typical durational patterns were the abnormally long and the abnormally short durations of fixation in relation to their positions on the line. Accordingly six different typical durational patterns were apparent for each of the three main parts of the line: its beginning third, its course or middle third, and its end or final third. Table XIV gives the typical movement-patterns, while Table XV gives the

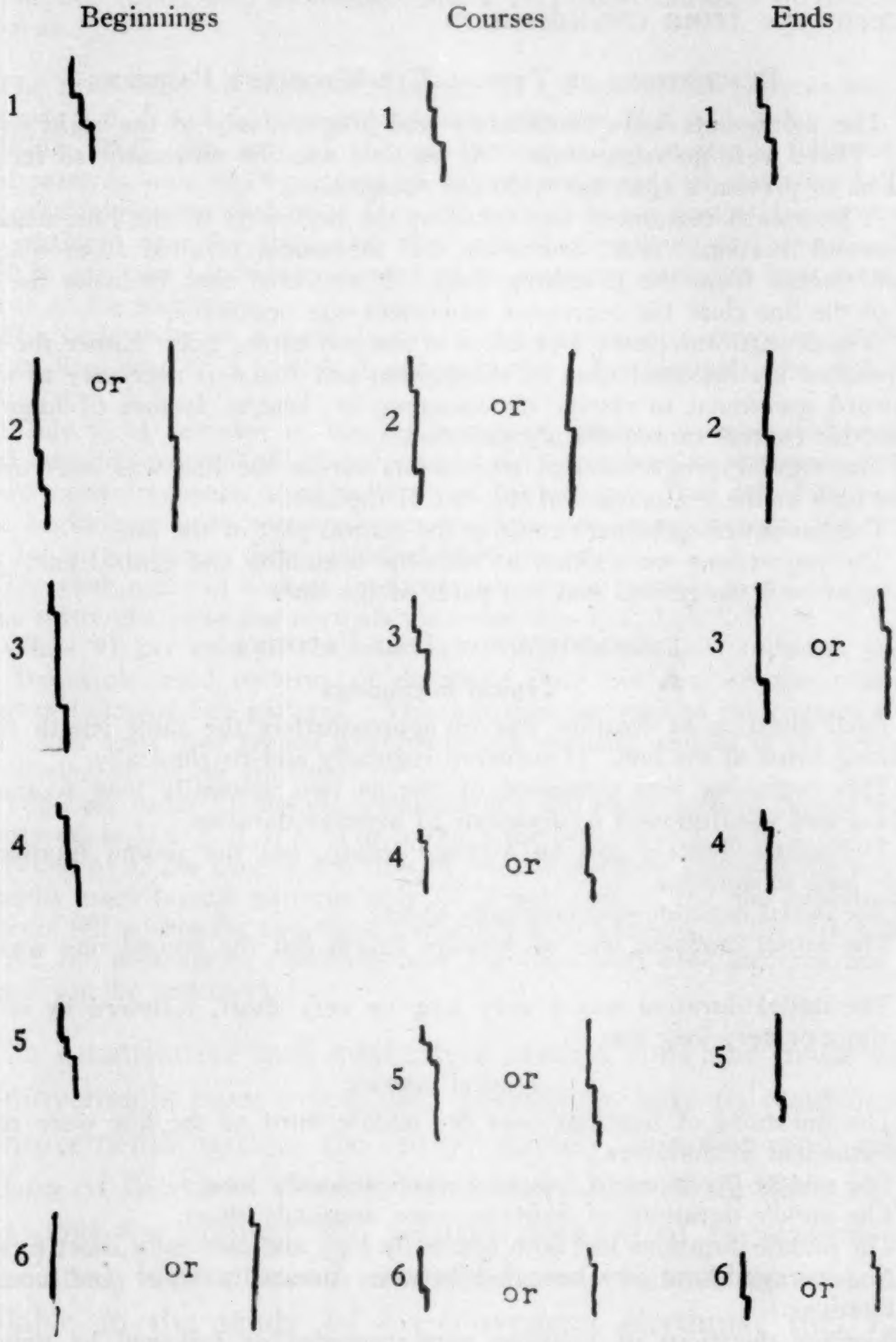
Table XIV. *Typical patterns of movements of eyes during silent reading*



typical duration patterns. Following the tables are descriptions of each typical pattern.

The reading records for both stutterers and normals were analyzed and each line of movements classified according to both

TABLE XV. *Typical patterns of durations of fixations of the eyes during silent reading*



the typical movement-pattern and durational pattern it most resembled. Data were thereby obtained from every line where the eye-movements were photographed satisfactorily, except for the reading of the first line of each of the three selections. Since this line was the test line when the eyes were being properly

focussed into the camera, it was thought best to exclude its pattern-type from consideration.

Descriptions of Typical Eye-Movement Patterns

1. The movements were consistently and progressively to the right over the line. There were no regressions. At no time was the movement so far to the right as to present a span too wide for recognition.
2. A backward movement was taken at the beginning of the line, usually on the second fixation. Most commonly this movement resulted from inaccurate return sweeps from the preceding lines. It appeared that to make the initial part of the line clear the regressive movement was necessary.
3. A backward movement was taken at the end of the line. Either the reader overreached his maximal span of recognition and found it necessary to make a backward movement to clarify the meaning, or, central factors of innervation beyond his control caused the phenomenon.
4. The regular progression of movements across the line was interrupted at points both at the beginning and the end of the line.
5. The backward movement came in the central part of the line.
6. The regressions were either at both the beginning and central parts of the line, or at both the central and end parts of the line.

Description of Time Patterns

Typical beginnings

1. Each duration of fixation was of approximately the same length for the beginning third of the line. It occurred regularly and rhythmically.
2. This beginning was composed of one or two unusually long fixations in duration and was followed by fixations of average duration.
3. The initial fixation had an average length, but the second fixation was unduly long in duration.
4. The initial duration was unusually short.
5. The initial duration was of average length but the second one was very short.
6. The initial duration was a very long or very short, followed by either a very short or very long one.

Typical courses

1. The durations of fixations over the middle third of the line were regular and rhythmical in character.
2. The middle durations of fixations were unusually long.
3. The middle durations of fixations were unusually short.
4. The middle durations had both unusually long and unusually short fixations.
5. An average duration alternated between unusually short and unusually long fixations.
6. Average durations of fixations were preceded or followed by unusually short durations.

Typical endings

1. The durations of fixations over the last third of the line were regular and rhythmical.
2. The line ended with two unusually long durations of fixations.
3. The line ended with an average and an unusually long duration of fixation or *vice versa*.
4. The line ended with a very short and a very long duration of fixation.

5. The line ended with a very long and a very short duration of fixation.
6. The line ended with an average and a very short duration of fixation, or *vice versa.*

1. The rank order of highest frequency of eye-movement patterns for stutterers was 1, 6, 2, 4, 3, 5. For normals the order was 1, 2, 6, 4, 3, 5.
2. While 76.27 per cent of the eye-movements of normals followed two typical patterns, only 49.74 per cent of the eye-movements of stutterers followed two typical movement patterns. This left only 23.73 per cent of the movements to be scattered over the four least used typical movements for normals, but it left 50.26 per cent of the movements to be scattered over the four least used patterns of the stutterers.
3. The rank order of highest frequency for durational patterns at the beginnings of lines was 1, 2, 6, 4, 3, 5, for stutterers. For normals, the rank order was 1, 2, 4, 6, 3, 5.
4. While 91.14 per cent of the beginnings of lines in normals followed two typical duration patterns, 81.91 per cent of the beginnings in stutterers followed the two most frequently used patterns of beginnings. This left 8.86 per cent of the beginnings to be scattered over the four remaining patterns for normals while for the stutterers there remained 18.09 per cent.
5. The rank order of highest frequency for typical courses was 1, 2, 3, 4, 5, 6, for the stutterers. For the normals the order was 1, 2, 3, 4, 6, 5.
6. While 91 per cent of the courses of lines in normals followed the two most frequently used patterns of duration, 77.47 per cent of the courses in stutterers followed two patterns. This left nine per cent of the courses following the four least used typical patterns by the normals, and 22.53 per cent being thus distributed for the stutterers.
7. The rank order of highest frequency for the occurrence of typical endings in stutterers is 1, 6, 3, 2, 4, 5. For normals the order was 1, 3, 6, 2, 5, 4.
8. While 84.93 per cent of the ends of lines in normals followed the two most frequently used typical patterns only 67.25 per cent of the end movements in stutterers fell within the two most frequently used patterns. This left 15.07 per cent for the normals to distribute over the four least used patterns and 32.75 per cent for the stutterers.

The quantitative and qualitative studies thus far made of the eye-movements have given data pertaining only to conditions of eye-movements within the lines; namely, number and relative position of fixations, duration and variability of duration of fixations, and the number and relative position of regressions. As in the study of the breath records, however, another approach is available in the study of eye-movement rhythms; this is, the direct inspection and description of the eye-movement records as found on the films. This kind of a study provided certain information relevant not only to the movements of the eyes upon the lines during silent reading, but also for the phenomena of functioning between the different lines as well as a comparison of lines as wholes, and to a very limited extent, certain performances

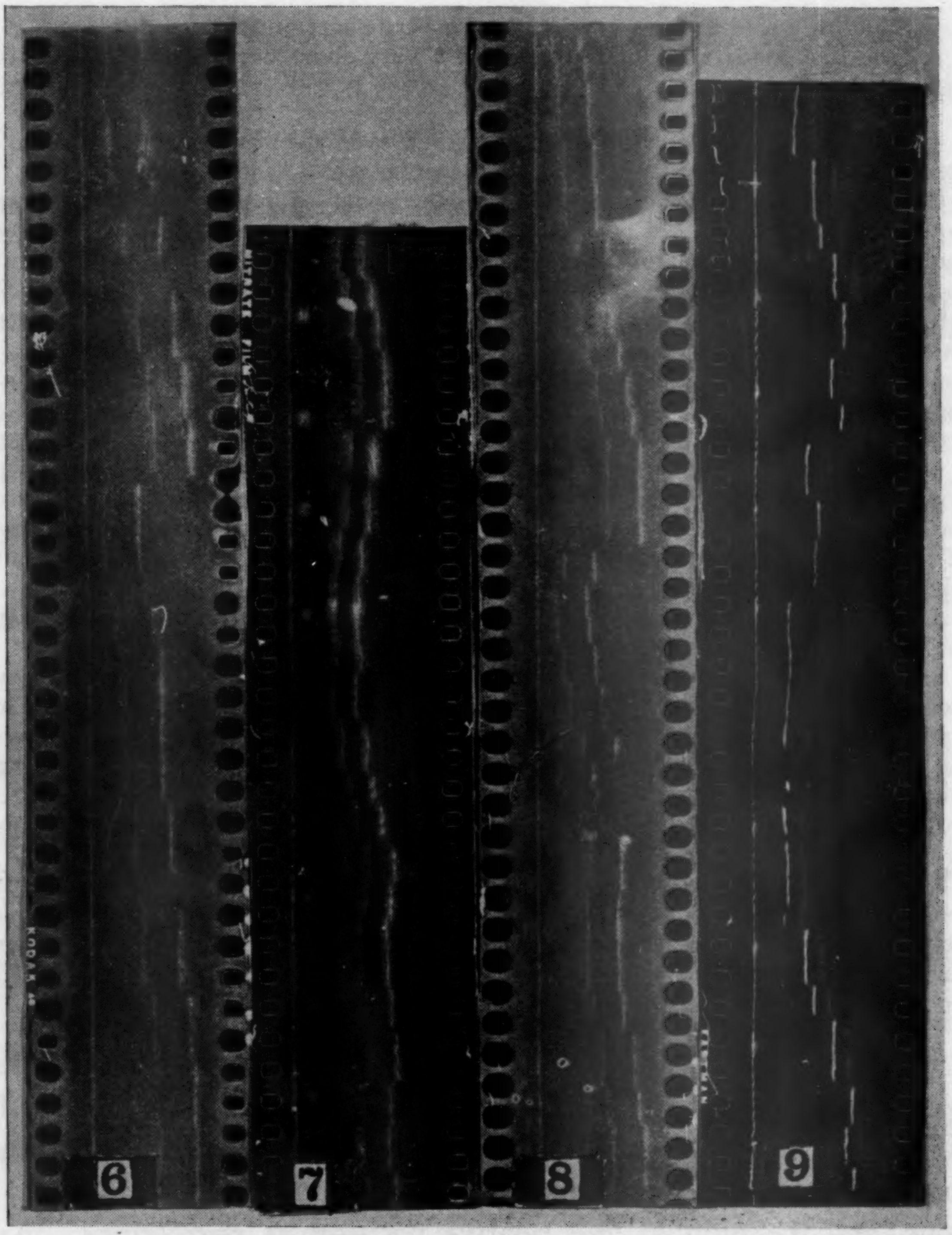


FIG. 6. Records of eye-movements of Ban (stutterer) during silent reading of social science material. In this figure and in all subsequent figures excepting Fig. 14, reading from left to right the first record is of movements of the head, the second, movements of the left eye, and the third, movements of the right eye.

FIG. 7. Records of eye-movements of Rie (stutterer) durnig silent reading of poetry.

FIG. 8. Records of eye-movements of Mck (stutterer) during silent reading of light prose.

FIG. 9. Records of eye-movements of Bul (stutterer) during silent reading of social science material.

of the eyes in the vertical plane. Also, certain deviations from the normal that have escaped the detection of our statistical and analytical studies became apparent.

In selecting the films for exhibition and description three criteria were held in mind: first, the phenomena selected must have been sufficiently frequent in occurrence to demonstrate that they were not chance occurrences; second, there must be adequate representation of the typical phenomena; third, special attention must be given phenomena not represented in any respects by previous parts of this study.

In interpreting the records the relatively straight line on the left is the head line. Superimposed on it are the spots made by the timing lamp every half second. In some of the selections these spots for various reasons did not appear, but they were usually found at other points on the same film so that rate of movement of the film could be ascertained. The movements of the two eyes as they traveled over a line were shown by the pairs of lines that break in more or less regular steps from the right to left down the film. The beginning of the reading of a sentence was represented by the white lines nearest to the left at the beginning of a record; as the eyes traveled toward the right of the page the eye-movements were shown on the record as appearing correspondingly farther down and to the right in the records. At the end of the sentence the eyes were presumably the farthest down and to the right with corresponding points on the record. The length of the parallel lines corresponded to the duration of fixations. Regressive movements were plainly apparent as movements toward the left or backward in relation to the progressive movements over the line toward the right.

All of the illustrations are from the records of stutterers. Fig. 6 is by Ban while reading two lines of social science material. The following are the lines which he was reading:

"toward business and social problems was
purely negative. Now it is interested."

The first line was read normally except for the two times when the eyes closed for an instant. The second line is characterized by extraordinarily long durations of fixations. The last duration was almost a second in length.

Fig. 7 is from one line of poetry as read by Rie. The line was as follows:

"For tomorrow I go over land and sea."

Instead of commencing the reading at the left hand side of the line, as a normal

individual would do, this stutterer started to read about one-third of the way from the right end of the sentence. Then her movements were to the end of the line on the right, then backwards over the whole extent of the line to the left. Then she traversed the line almost completely to the right after which the eyes were again shifted back towards the center of the line where they continued a semi-spasmodic series of forward and backward movements. It will be seen that for the most of the time the eyes were in a state of reversal of their movements. The movements forward were generally with shorter durations than those backward. While the fixations of the normals were on the average about one-fourth of a second in duration, these movements appear to be less than one-sixth of a second in average duration of fixation. The light spot near the fourth helf-second spot from the top is a vertical movement of the eyes.

Fig. 8 is from the light prose as read by Mck. The two lines are as follows:

"by the supreme court of the United States
which has sustained the validity of a clause."

The first line ends with an abnormally long fixation of approximately one-half second duration. Just before it are five abnormally short fixations only about one-seventh of a second each in duration. In the middle of the line both eyes blinked. The second sentence brought out almost the whole gamut of abnormalities. While the first regression is not especially noteworthy the second one is quite distinctive. After traversing the line for about two-thirds of its length in a normal manner, the eyes jumped backward, or to the left, completely to the beginning of the line. After making one short fixation slightly to the right they then jumped over near the point on the right to which they had approached previous to the regression. At this point they went into a vertical spasm for a short time, after which they made two regressive movements of unusually long duration, followed by fixations to the right, also of unusually long duration, until the reading of the line was completed.

Fig. 9 is one line of social science material reading by Bul. The behavior of the eyes here are somewhat similar to those in Fig. 5 by Rie. The reversals, however, are wider in span and there is not the complete coverage of the entire line while going backward as is indicated in Fig. 5. After advancing over about two-thirds of the way in a rather uncertain rhythm through three wide regressive movements alternated with only small forward movements the eyes are blocked and apparently in spasms at the beginning of the line for almost one and one-half secs. after which the eyes then finished the line in a manner not especially abnormal. In the midst of the long fixation at the beginning of the line there was head-movement and vertical movements of the eyes. The strain incident to this prolonged fixation may have been the cause of the eyes blinking three times at this point.

Fig. 10 is the reading of two lines of light prose by Fis. In the first line the reading, with the exception of one quite short duration, appears normal until the eyes come to the end of the line at the right where after a rather long fixation, they regress for a fixation, and then go back to the end for a final fixation. In the second line the eyes regress back to the beginning of the line three times before finally completing the line. In this process the first half of the line was covered four times. The fact that the longest durations come at the extreme left is further evidence of the tendency of the eyes to work toward that direction.

In Fig. 11 the reading of Fis continues on the same selection as above for two more lines. The striking feature is the unusually long duration of fixation at the end of the first line. The record indicates a very abnormal condition in the second line. Instead of progressing across the line in the normal manner

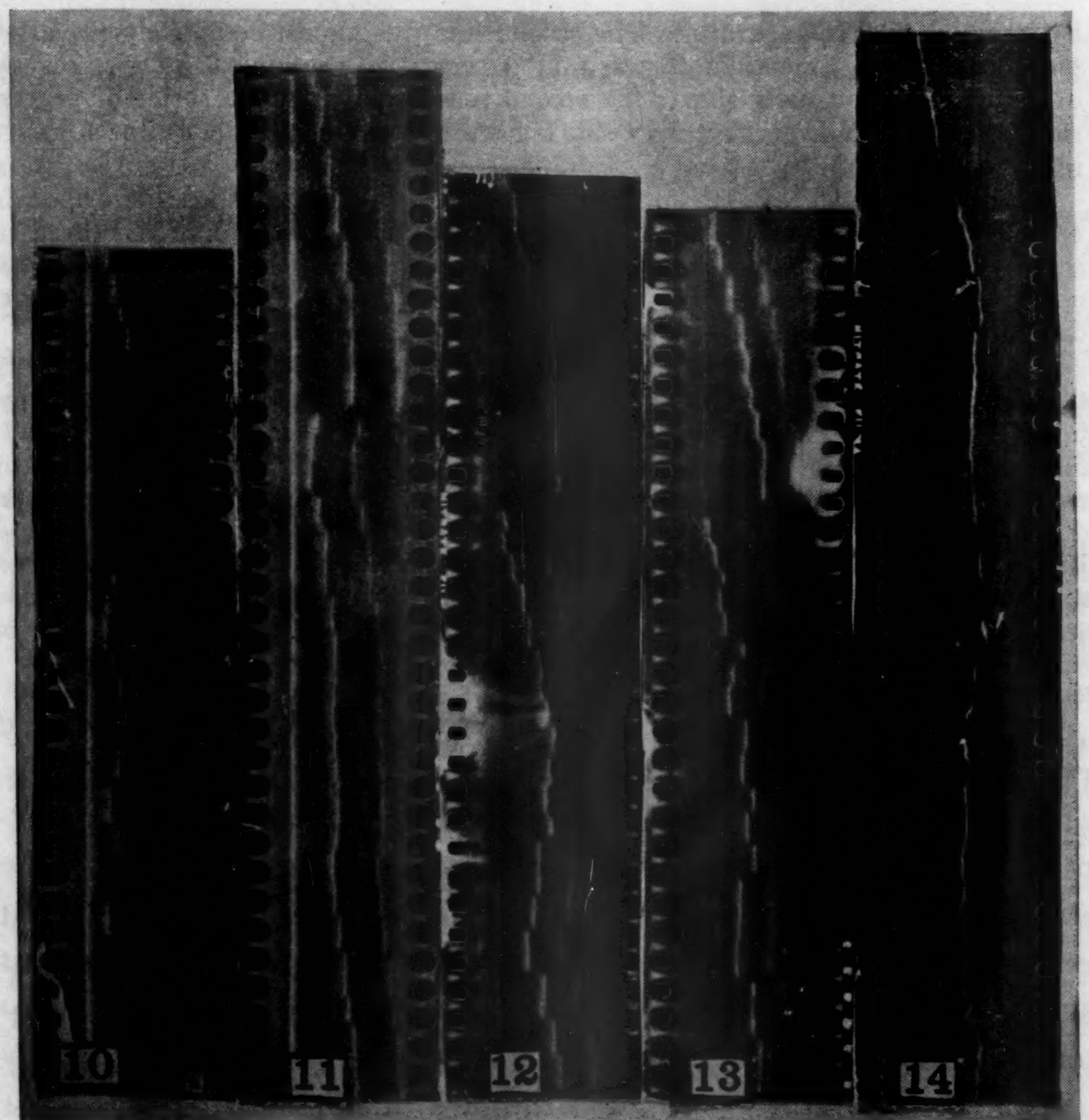


FIG. 10. Records of eye-movements of Fis (stutterer) during silent reading of light prose.

FIG. 11. Records of eye-movements of Fis (stutterer) during silent reading of light prose.

FIG. 12. Records of eye-movements of Joh (stutterer) during silent reading of social science material.

FIG. 13. Records of eye-movements of Joh (stutterer) during silent reading of social science material.

FIG. 14. Record of eye-movements of the right eye of Vau (stutterer) during silent reading of social science material.

with a series of rhythmical jerks or jumps, the movements are almost reduced to a series of slides sometimes backward and sometimes forward. Figs. 7 and 14 also show this tendency at points. This line required about three times the normal amount of time for reading.

Fig. 12 gives the eye-movements of Joh on two lines of social science material. Except for the variation in duration of fixations the first line is normal in the movements represented. The waviness of the last fixation was probably caused

by vibrations in the apparatus. The second line was almost completely traversed three times: the first time forward in a series of rhythmical jumps, several of which were unusually short; the second time backward by a series of regressions, several of which were very short in duration; and the third time forward in a rapid fashion.

Fig. 13 was made by Joh in reading two lines following those described in Fig. 14. The first line has an unusually large number of fixations, three of them very short in duration. The second line presents about three times the normal number of fixations, with both abnormally long and abnormally short durations of fixations. About one-third of the movements are backward.

Fig. 14 was taken from the reading of social science material by Van. Only the record of one eye is shown. Since the head-line is not in the record it is impossible to tell how much of the vertical movements are the result of head-movements and how much of them are caused by actual vertical movement of the eyes. In all probability the wavy movements are head-movements while the longer curves and slants are evidence of breakdowns in the jerks and jumps of the eye causing it not to fixate in the normal way but to slide or somewhat roll over the line. Tendencies toward this kind of behavior are also apparent in Figs. 7 and 11. Most of the eye-action seems to be very narrow in range and largely concentrated on the middle portion of the line.

IX. A study of the reading ability of stutterers by standardized reading tests. In this part of the experiment the aim was to obtain, through the use of standardized silent reading tests, information to help answer the following questions: (1) Are the stutterers as a group below normal in comprehension of silent reading? If they are below normal, in which of the various unit skills—*i.e.,* sentence comprehension, word comprehension, sentence organization, paragraph organization, and location of information—involved in comprehension, are those abnormalities most apparent? (2) Are the stutterers as a group below normal in rate of silent reading? (3) Do the stutterers rate as high in reading efficiency as they do in general intelligence? (4) Is there any relation between the amount of dysintegration of breathing and eye-movements in the stutterers and their efficiency in either comprehension or rate of reading?

Three considerations were of importance in selecting the silent reading tests: (1) the tests selected must be adapted to the mental maturity of the particular group; (2) there must be norms satisfactory for comparative purposes that can be applied to the particular group to be tested; (3) the tests must be adequate, reliable and valid in respect to the factors they purport to measure. Analysis of the case data pertaining to the stutterers revealed a rather curious situation from a standpoint of group testing. Of

the 18 stutterers, five were college graduates, four were in college, five were in senior high school, three were in junior high school, and one was in elementary school. Obviously no one reading test could meet the requirements of such a wide range of maturity.

In order to have a measure whereby all these different subjects could be given a rating in accordance with their grade levels and the reading efficiency of the group as a whole evaluated, it was necessary to give more than one test and to have the findings of all the tests transmuted into the terms of a common measure.

After surveying the standardized tests available for use and the norms resulting from their standardization, the best procedure appeared to call for two tests: the Iowa Silent Reading Advanced Examination, by H. L. Greene and A. N. Jorgenson, and the Monroe Silent Reading Test 1. Although the Iowa Comprehension Test, the Haggerty Silent Reading Examination, and the New Stanford Silent Reading Test were all given to various of the stutterers the results did not appear to be generally as valid and adequate for this particular group as did those of the first two tests above mentioned.

All but six of the stutterers fell within the seventh to twelfth grade range of the Iowa High School Reading Test. Since this test was by far the most comprehensive and was a much longer and generally more difficult test than any of the others and, what was quite important, since there was a wider range of norms available, it was considered the most appropriate to use for the five stutterers who were graduate students, the four college students, and the eight students in high school. This left but the one subject in the fourth grade for whom a different test had to be given. Since the Monroe Test measured rate as well as comprehension, it was selected for this subject in preference to the New Stanford. With this arrangement it was possible to retain the standards and norms of the Iowa Test as the common measure of all, after transmuting the results of the one subject who was given the Monroe Test into terms of the Iowa Test.

Apparently much more thorough and comprehensive than any other examination available, the Iowa Tests measure a wide range of skills indispensable to effective reading of the work-

study type, and are therefore especially appropriate to use for diagnostic purposes. Four major aspects of reading ability are measured; namely, (1) comprehension, (2) organization, (3) ability to locate information, and (4) rate of reading. These fields are covered by means of six different types of tests requiring a total testing time of 56 min. According to the authors (14), it may be said that while this test may seem unduly long to those accustomed to a less reliable measurement, it has been found that this length of test is a minimum if reliable results are to be obtained. The test booklet is arranged in such a manner that the test is given in two sittings of 28 min. each. This procedure was considered not only fundamental to the effective use of the test, but it also eliminated almost entirely the element of fatigue.

The unit skills contributing to the subject's ability to read which are measured by the Iowa Silent Reading Advanced Examination are as follows (29):

Test 1. Paragraph Comprehension
- A. Social Science Material
- B. Science Material
- C. Literature Material

Test 2. Word Comprehension
- A. Social Science Vocabulary
- B. Science Vocabulary
- C. Mathematics
- D. English Vocabulary

Test 3. Sentence Comprehension

Test 4. Sentence Organization

Test 5. Paragraph Comprehension
- A. Selection of Central Thought
- B. Outlining
- C. Organization of Paragraphs

Test 6. Location of Information
- A. Use of Index
- B. Selection of Key Words
- C. Alphabetizing

Test 7. Silent Reading Rate

Ordinarily, there is a high correlation between general mental ability and reading efficiency for unselected individuals. The correlation between the Terman Group Tests of Mental Ability and the Iowa Silent Reading Advanced Examination is .827 (14). If stutterers have reading disabilities, there should be, as a consequence, a marked disparity between their relative standings in intelligence tests and reading tests. Therefore, in order to

examine further the reading ability of stutterers they were each given an Otis Self-Administering Test of Mental Ability (24) of the form adapted to the ages involved. The average coefficient of correlation between the two forms of the Otis advanced examination is .921; between the two forms of the intermediate examination the coefficient of correlation is .948.

Comparison by percentile ranks was decided upon as the most suitable procedure for working up the data from the tests of all the subjects. This method permitted the combining of results from all the tests for both the lower and higher grade levels for comparative purposes on the one scale.

The percentile norms applicable to the 7th to 12th grades were based on 1,438 cases (14); the norms used for the older subjects were based on tests from 160 University of Iowa juniors and seniors (19). The norms for the Otis Tests were based on 2,516 subjects (24).

The method of correlation used was according to the *Pearson* product-moment formula for which deviations are taken from the actual averages of the two distributions (9).

The following facts are apparent from an analysis of test scores and the correlations:

1. The stutterers were found to be 11.84 points below the 50th percentile in comprehension and 24.84 points below the 50th percentile in rate of reading. The subjects of the control group were 1.11 points above the 50th percentile in comprehension and 10 points below the 50th percentile in rate of reading. Direct comparison between the stutterers and the control group showed the stutterers 12.95 points lower in comprehension and 14.84 points lower in rate of reading in spite of the fact that both groups were practically of the same intellectual level. In terms of grade levels, the stutterers were, roughly speaking, about one grade below normal in comprehension and two grades below normal in rate of reading.

2. The fact that the stutterers presented reading disabilities was further emphasized by a comparison of their reading scores with their mental tests. The correlation of the Iowa Silent Reading Advanced Examination scores with the Terman Group Tests

of Mental Ability scores is .827 for normal speakers (14). However, instead of a close correspondence between the scores in reading and in intelligence tests. there was a wide disparity between these factors in stutterers. In comprehension the stutterers rated 35.31 points on the percentile scale and in rate of reading 48.31 points below their intelligence ranking. Our normals ranked in comprehension 19.02 points and in rate of reading 30.13 points below their standing on intelligence scores. Therefore, with the factor of intelligence held constant the stutterers were found to be 21 per cent below the control group in comprehension, and 25.9 per cent below this group in rate of reading. Interpreted from the percentile norms of the Iowa Tests this would show the stutterers to be about one grade below their control group in comprehension and two grades below in rate of silent reading.

3. The disparity between the general intelligence and reading ability was further marked when the true intelligence of the stutterers is taken into account. *Durrell* (3) has shown that individuals who are reading disability cases rate 4.57 points in I.Q. below what their score would be if they were not required to read for the tests. In place of an average I.Q. of 111 scored by the stutterers the actual score on this basis for them would be 115.57, which would have placed them in approximately the 80th percentile in place of the 73rd. On the percentile scale the disparity would then be, according to the Otis Interpretation Chart (24), 41.84 points below normal in comprehension and 54.84 below normal in rate. On the same basis they are about 21 points on the percentile scale below their control group in comprehension and 31.9 below in rate of reading.

4. Of the five unit skills in comprehension tested by the Iowa Examination, the stutterers were shown to be equal to the control group in two and markedly below in three. In paragraph meaning the stutterers were 29.9 points below the normals on the percentile scale; in word meaning they were 19.93 points below; in sentence comprehension they were 15.78 points below; in sentence organization they were 2.83 above; in paragraph organization they were 22.84 points below; and in locating information they were 1.13 above the control group.

In both of the unit skills in which the stutterers were normal in their scores success depended relatively more upon the so-called pure mental processes than upon efficient eye-movements. On all the other tests demands upon the eyes were much greater. Inspection of all the tests shows that the stutterers were less efficient as it became more necessary for them to make many rapid or many long and sweeping movements of the eyes in order to find the proper answer. In all the tests in which the stutterers were below the control group it was necessary for them to cast their eyes back and forth and up and down over the entire extent of the page much more than in the other tests.

Table XIV shows the correlation of mental ability with rate of reading to be .399 higher in normals than in stutterers. It is .064 higher in comprehension for the stutterers.

TABLE XIV. *Correlation of percentile ratings in silent reading* with percentile ratings in intelligence*

	Stutterers r	Normals r
Rate of silent reading..................	.031±.118	.43±.119
Comprehension of silent reading........	.474±.112	.410±.111

* All correlations are based on the average of the three samples of reading given each subject.

6. Table XV indicates that the correlation of the coefficient of variation of amplitude of expiration with rate of reading is .029 higher for stutterers than for normals. It is likewise higher for stutterers in the other phases of breathing; .204 in duration of inspiration, .026 in amplitude of expiration, and .096 in duration of expiration, an average of .139 higher correlation for stutterers.

TABLE XV. *Correlations of coefficients of variation of breathing movements during silent reading with percentile standings for rate of silent reading*

	Stutterers r	Normals r
Amplitude of inspiration..............	—.336±.140	—.207±.909
Duration of inspiration................	—.416±.130	—.212±.856
Amplitude of expiration...............	—.329±.111	—.303±.130
Duration of expiration.................	—.417±.131	—.221±.112
Ave....................................	—.374	—.235

7. In Table XVI the correlations of breathing variability with efficiency in comprehension are given. As between the amplitude

of inspiration and comprehension, the normals have .116 higher correlation; for duration of inspiration and comprehension the normals show .077 greater correlation; for amplitude of expiration and comprehension, the stutterers give a .065 higher correlation; for duration of expiration and comprehension, the stutterers have .182 higher correlation. For all phases of breathing the correlation with comprehension is .056 higher for the stutterers.

TABLE XVI. *Correlations of coefficients of variation of breathing movements during silent reading with percentile standings for comprehension of silent reading*

	Stutterers r	Normals r
Amplitude of inspiration	—.251±.56	—.367±.137
Duration of inspiration	—.143±.126	—.303±.145
Amplitude of expiration	—.388±.135	—.323±.151
Duration of expiration	—.312±.437	—.131±.115
Ave.	—.276	—.281

8. Comparison of Table XV with Table XVI shows that both normals and stutterers have very little difference between the relation of rate of reading to breathing movements and the relation of comprehension to breathing movements.

9. Table XVII indicates that the normals have a slightly higher correlation than do the stutterers between the coefficient of variation of the duration of eye-fixations and the rate of silent reading. Stutterers have a slightly higher correlation than do normals between the coefficient of variation of the duration of eye-fixations and comprehension of reading material.

TABLE XVII. *Correlations of percentile standings in silent reading with coefficient of variation of the duration of fixations of eye-movements*

	Stutterers r	Normals r
Rate of silent reading	—.225±.285	—.230±.709
Comprehension of reading	—.193±.999	—.147±.114

10. In Table XVIII are given the correlations between the variability in breathing movements and in duration of eye-fixations. Between amplitude of inspiration and eye-fixations there is a slightly higher correlation for stutterers. Between duration of inspiration and eye-fixations there is a slightly higher

correlation for normals. Between amplitude of expiration and eye-fixations and between duration of expiration and eye-fixations there is a much higher correlation for stutterers than for normal speakers. As between the stutterers and normals in all phases of breathing, the correlation with the eye-movements is .083 higher for the stutterers. It is to be noted in many of the items of these tables that the probable errors are somewhat high and the relations indicated are low. However, there appears consistency in the relations in all the phases involved. All the correlations between variability in breathing movements and reading efficiency, and variability of eye-movement fixations and reading efficiency, are negative. That is, as variability, and hence dysintegration increases, reading efficiency decreases. If the factors of the experiment have been under proper control, the foregoing correlations are in all probability indicative of the relations between the dysintegrations and reading efficiency.

TABLE XVIII. *Correlations of the coefficients of variations of breathing movements with the coefficients of variation of the duration of fixations of eye-movements during silent reading*

	Stutterers	Normals
	r	*r*
Amplitude of inspiration	.438±.118	.341±.140
Duration of inspiration	.426±.130	.457±.726
Amplitude of expiration	.471±.119	.369±.104
Duration of expiration	.253±.574	.220±.810
Ave.	.397	.347

X. General summary and conclusions. The purpose of this experiment was to ascertain whether the known dysintegrations in stutterers during overt speech were sufficiently deep seated to be evident in the closely related implicit activities of silent reading and reasoning. Three approaches in the investigation of the dysintegrations were utilized; first, a study of the extent and form of the breathing dysintegrations through the measurement, analysis, and description of kymographic breathing curves; second, an investigation of the rhythms of eye-movements through the measurement, analysis, and description of eye-movements photographically recorded; and third, a study of the dysintegrations as measured by standardized silent reading tests.

In order to bring various factors of the experiment under control the 18 stutterers and 18 normal speakers were paired in regard to age, mental brightness, and grade level. The same reading and reasoning materials, selected according to the maturity of the individuals, were used under uniform conditions by both members of each pair for the breathing as well as the eye-movement records. Data from all subjects were treated by the same quantitative, qualitative, and descriptive procedures for the study of variability.

In practically every phase of the experiment the results showed various and marked dysintegrations in the stutterers during silent reading and reasoning. In breathing the stutterers showed 121 per cent greater variability than the normals in amplitude of inspiration; 51.2 per cent greater variability in duration of inspiration; 112.3 per cent greater variability in amplitude of expiration; and 51.5 per cent greater variability in the average duration of expiration. In relation to rest breathing stutterers, during silent reading and reasoning repressed the amplitude of their breathing more than did normals. With the increase in difficulty of the reading material and reasoning, the increase in the dysintegrations were much more rapid and pronounced in the stutterers. In all phases of the breathing, stutterers showed approximately two-thirds as much variability during silent reading as other experimenters have shown them to present during overt speech.

The qualitative analysis of the breathing curves for typical patterns of inspiration and expiration movements showed that stutterers employed with much greater frequency all of the six typical patterns; that a much larger majority of the movements of normals followed only one or two characteristic patterns. Also the order of frequency in the usage of typical patterns was different in the stutterers than the order used by the normals.

The direct procedure of inspection utilized in the descriptive study of the breathing records indicated pronounced disturbances in amplitude of breathing, as well as marked irregularities in duration of inspiration for stutterers. Blocking of the entire

breathing apparatus and tonic and clonic spasms appeared at times. Occasionally synchronization between the different parts broke down altogether, resulting in independent action which sometimes brought the different parts into opposition in their actions.

The quantitative study of eye-movements showed that stutterers had an average of 22.34 per cent more fixations per line than non-stutterers, and 126.5 per cent more regressive movements. The average duration of fixations for non-stutterers was 10.3 per cent longer than for the stutterers. The average perception time per line was 4.09 per cent longer in duration for the stutterers. The variability of the duration of fixations was 44.52 per cent greater for the stutterers.

The qualitative study of the eye-movements revealed that only 49.74 per cent of the eye-movement patterns over the lines of reading matter of the stutterers followed as few as two typical patterns of movement. At the same time 76.27 per cent of the movements made by normals followed only two typical patterns. Duration patterns at all parts of the line were similarly more irregular and lacking in rhythm for the stutterers. As with the breathing patterns the stutterers followed a different order in the frequency of the usage of the typical patterns of both movement and duration.

The descriptive study of eye-movements revealed such various abnormalities in stutterers as unusually long and unusually short durations of fixation, an unusually large number of fixations per line, an unduly large number of regressive movements with tendencies for much backward action, conditions of high tension and spasm, and occasional loss of normal ability to fixate.

The study of dysintegrations as measured by silent reading tests brought out the fact that stutterers appeared to be approximately one grade below normal in comprehension, and two grades below normal in rate of reading. When their true intelligence was considered the disparity was further increased about one-half grade. Of the particular skills involved in silent reading, the stutterers were deficient only in those making heavy motor demands upon

the eyes. Correlations of reading achievement with breathing and eye-movement dysintegrations demonstrated somewhat significant inverse relations.

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CAUSES OF SOCIAL MALADJUSTMENT IN CHILDREN

by

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I. Introduction. The purpose of this study was to see if by the utilization of psychological, medical, and sociological principles, it might be possible to discover the causes of maladjustment in children. In arriving at these causes of maladjustment over 400 problem cases referred by the Juvenile Court, the social agencies, the public schools, and individuals have been carefully studied through the psychological, medical, and sociological methods of approach. The value of this study presumably lies in the concreteness and detail with which these causes are described.

The Boys' Work Committee of the Rotary Club of Toledo, Ohio, as a growth of their coöperation with the Juvenile Court of that city had made a special investigation of the problem of delinquent boys. The report of this investigation was so convincing that the Boys' Work Committee met with the Superintendent of Public Schools and asked him to make suggestions as to how the problem could best be met. His suggestion that a trained psychologist be obtained to work with a group of the boys and gather data on the basis of which needed legislative changes could be inaugurated met with instant acceptance.

The writer was engaged to come to Toledo and work with a group of delinquents for a period of six months. He was to be given a free hand in the experiment and the coöperation of all the agencies in the city interested in this problem was to be secured for him. The work was begun in January, 1924, and although this study covers only the period between that time and June, 1926, the work then inaugurated is still going on.

The procedure of having the writer work with a small group of the worst boys in the city under classroom conditions was abandoned, because there were so many calls for his assistance in connection with the Juvenile Court and other agencies in the city. Instead a Juvenile Adjustment Agency was established with the writer in charge and with provisions for personal interviews and individual study in offices away from the school building. The Agency was available for public and parochial schools, Juvenile Court, the Social Service Federation, and the other agencies which might find its services desirable. It was also open to individuals, both parents and children. In this way it was hoped to broaden the field of usefulness for the agency, and to provide the opportunity for diagnostic and adjustment procedure for a great many more

cases. After the appointment of the writer as referee in the Juvenile Court all of the cases coming before the court were referred for study and recommendations.

The problem case was referred by the Juvenile Court to the writer, who made or supervised the social, medical, educational, intellectual, vocational, and personality study. The summary of findings, together with recommendations were then submitted to the Judge who ordered treatment which was carried out through the medium of agencies or whatever institution was recommended by the Agency. The financial support was provided by the Rotary Club and the Board of Education.

Inasmuch as this study confined itself to an analysis of the causes of delinquency, no further mention will be made of the treatment and results. It was decided to limit this study to causes of delinquency, because sufficient time had not yet elapsed to determine accurately the final results of the adjustment procedure.

II. Method of obtaining data. In obtaining the information necessary for a thorough and accurate analysis of the etiological factors of delinquency it is important to exhaust every source of information in the community. It is also necessary to inform one's self of all the varied influences, hereditary, environmental, physical, and mental, which have left their imprint on the individual under consideration. In this study it was found necessary to discover more than the mere facts indicated by a study of the case. It was necessary to make a comprehensive and thorough study of the factors which might influence the child's development of antisocial attitudes and behavior patterns.

A. Criticism of method of obtaining data: 1. Delinquency The records of the Juvenile Court were consulted for the histories of the delinquencies of the individual. These were unfortunately very incomplete, merely mentioning the type of delinquency, theft, truancy, burglary, *etc.* When the delinquent was referred by some of the agencies or an individual, as complete a report of his antisocial behavior as possible was obtained. There was an attempt made to obtain from the boy himself an accounting of every delinquent action, stressing the first of these experiences and what mental content was present just prior to and during the progress of the delinquent act, who the companion was, and what the attending circumstances were. The psychogenesis of these actions was investigated as completely as possible with a view to determining whether there were any obsessive ideas in mind at

the time. An attempt was also made to discover to what extent the individual was a chronic delinquent, and the nature of his antisocial behavior. The individual was also asked to give reasons for his act and an attempt was made to analyze his attitude toward his delinquency and discover how much real appreciation and insight he had with reference to desirable social relationships. The effect of imprisonments and institutional detentions was studied in this connection.

2. Family history. An outline of information for use at the Juvenile Adjustment Agency was compiled after a study of those used by various clinics and social agencies. In addition to the case history obtained from parents, relatives, social agencies, employers, family physicians, teachers, and attendance officers, sections were included in the interview on family conditions, parental control, housing conditions, and environment. These were found to be very important as the patient often gave information about family conditions such as immorality, bootlegging, other forms of lawlessness, drunkenness, quarreling in the family, friction between various members of the family, partiality toward other children, too much or too little strictness, brutal punishment, sleeping conditions, *etc.,* which could not be obtained from parents or relatives.

3. Medical history. The outline for the medical history of the subject was also a composite result of a study of the blanks from various child guidance clinics, hospitals and other agencies. It included not only childhood diseases and injuries, but also physical irritations and enuresis. There were only a few cases where the medical examination indicated a physical condition which might account for the delinquent action and where the medical staff was able to recommend anything in the way of medical treatment which would, in its opinion, bring about an improvement in the behavior of the boy.

4. Personal history. The developmental part of the personal history was obtained from parents and relatives according to the Case History outline. Many times information about the child's attitude toward his parents and teachers was not available, because they had not observed the child very closely during the period of early childhood and adolescence. The parents knew very little

about the boy's sex habits or about his mental content. The boy had to be consulted for the detailed account of his interests in school and his attitude toward teachers and other students, and an attempt was made to discover and evaluate the influences which school life had brought to bear on the individual delinquent. When the child was in school his work habits were obtained from the teacher whenever possible. If he had been employed these were obtained from him and from the employer.

The parents and relatives furnished descriptions of his companions, but the chief reliance was placed in his own story of his companions. The first bad companion, if he could be remembered, was found to be particularly important. His tendency toward extroversion or introversion could be pretty accurately determined from the study of his companions. From companions it was very easy to go to sex habits, as these usually originated in the companionships of the boy. Companions who were interested in undesirable sex activities were usually remembered better than those who were merely lawless.

The boy's interest and participation in sports and activities helped to determine the absence or presence of wholesome outlets of amusements and recreation. Especially significant was the type of movies he attended or the habit of loafing around poolrooms and attending public dances. It was important to discover excessive indulgence in narcotics and stimulants as the delinquency sometimes hinged on these habits. In connection with sex habits, interest in stories and pictures, which might be used as masturbation phantasies, must be discovered, and an attempt was made to do this.

Religious influences were found to have little importance as causal factors of delinquency, unless the almost universal absence of any real religious feeling can be considered a cause of delinquency. The dominating interest of the individual, the thing which he would rather do than anything else, was often valuable, not only in discovering etiological factors, but in prescribing treatment.

5. Psychological findings. In determining the intellectual status of the individual chief reliance was placed upon a Stanford Revision of the Binet Test, but whenever any doubt as to the

accuracy of this test in an individual case existed, it was supplemented by other tests. These tests were supplemented by a careful observation on the part of the examiner and the record of the boy's conduct responses to school and work stimuli. These impressions were brought together under headings taken in the main from *Spaulding's* Personality Chart which included not only intelligence but also such things as character traits, emotionality, special abilities and disabilities, manner and attitude, educational, and work abilities.

Very few psychological tests have been worked out to chart an individual's special abilities and disabilities. One can obtain suggestions as to these special abilities and disabilities from results of intelligence, educational, and mechanical aptitude tests. Further information can be obtained from a careful observation of the individual. His interests as shown in the tests and his behavior and work record can be used to some extent to discover his aptitudes. In determining the special abilities and disabilities of these individuals it was necessary to use the method described above together with tryouts in shops and branches of high school work and interest blank records.

It was comparatively easy to determine the educational status of the individual. It was only necessary to administer the educational tests available and to supplement these by the report of teachers to obtain the educational status of the individual. The subject was classified under childish, adolescent, adult, follower, and leader as to type. His temperament was determined by combining results of investigation into the personal history and his reactions to the tests.

One of the most important items of information needed was a knowledge of the traits which the individual possessed. While it is true that traits are usually specific and tied up with certain specific situations there are general attitudes and types of responses, a knowledge of which aided in a more or less complete understanding of the individual. The only test which seemed to have value in discovering the traits of the individual was the *Downey* Will Profile, but chief reliance had to be placed on per-

sonal observation of the individual, reports from parents, teachers, and others with whom the boy came into contact. Traits have been mentioned in causations only when there was a demonstrable relation existing between the trait and the anti-social conduct. A list of 45 traits was checked on the basis of the above study of the individual. The individual's manner was observed during the interview and the tests and an estimate was made on the basis of these observations. The same thing was done with reference to his attitude.

Very little dependence could be placed upon tests of emotionality in estimating the part which lack of emotional balance played in the maladjustment of the individual. A report was obtained of his behavior in the schoolroom, in the shop, the home and on the streets. These combined gave a fairly accurate index to his emotionality. Very seldom has it been possible to demonstrate the presence of any mental irritations in the delinquents. There were occasional cases which were undoubtedly subject to constant mental irritations, but these were the exception rather than the rule. The presence of an inferiority complex was determined by means of the interview, and many causes of the feeling of inferiority were discovered.

III. The data. In setting forth these data a very difficult problem presented itself. The complexity of causation and its interrelationship in the different cases make it practically impossible to illustrate a single cause by a single case. This method would be entirely too arbitrary and contrary to the real situation as it presented itself in the study of delinquency. In a careful analysis of 414 cases some 200 odd causes emerged. Below will be found a list of causes together with the number of individuals in which each was present. The table shows the entire analysis which was made as a result of this study. The outline presents all of the larger divisions in the analysis and the individual causes within each group which occurred with the greatest frequency. The total number of individuals in which the causes were present is shown for each major division of the table, and within the sub-groups, the causes are tabled as they appeared in boys and girls.

Causations

	Boys	Girls	Total
A. Social and environmental influences			
I. Defective home conditions			340
a. Lack of supervision and discipline			147
Father absent and mother unable to exercise adequate control	21	1	22
Insufficient control exercised by parents	38	12	50
Mother employed leaving child too much unsupervised	11	2	13
b. Friction in family			62
Friction between parents on question of discipline resulting in inconsistent discipline	11	0	11
Father unreasonable in his discipline	7	3	10
Friction with step-parent	6	2	8
c. Other undesirable environmental influences			69
Poverty	14	2	16
No home life	9	4	13
Changing home conditions making for instability and irresponsibility	12	0	12
d. Low moral standards			62
Ignorance on part of parents	19	31	50
Degenerate father	0	5	5
Mother immoral	1	3	4
e. Too much supervision and discipline			7
Parent making all decisions hampering moral development of child	7	0	7
II. Neighborhood			24
Lawlessness, adult or juvenile	15	1	16
III. Bad companions			236
a. Companions not delinquent, influencing by suggestion and through fear			46
Influence of relatives	14	0	14
Companions mutually influencing for bad	9	0	9
Association with older companions	4	0	4
b. Lawless companions			147
Association with companions who steal	75	6	81
Association with lawless companions	29	2	31
Association with boys who stole autos	21	0	21
c. Companions engaging in sex perversions			8
Companions engaging in sex perversions	3	1	4
Association with sex perverts from whom he obtains money	1	0	1
Association with man of position who used him homosexually	1	0	1
d. Immoral companions	13	22	35
B. Psychological			485
I. Defective or unsatisfied interests			83
a. Recreational			30
Desire to drive autos	8	0	8
Desire for adventure and good time	5	2	7
Lack of healthy interests	3	0	3

	Boys	Girls	Total
b. Educational and vocational			29
Dislike for type of school work offered	23	2	25
Not allowed to work	1	1	2
Wish to gain notoriety	1	1	2
c. Sex habits			19
Lack of proper sex information	11	5	16
Abnormal interest in sex matters	1	2	3
II. Mental abnormalities and peculiarities			330
a. Instability			40
Emotional, unstable, restless individual	10	2	12
Shiftless, vacillating nature inclined to avoid issues	10	1	11
Irresponsibility, lacking foresight	8	1	9
b. Abnormal introversion			13
Seclusive, brooding, introvertive type	8	0	8
Persecution complex	1	1	2
c. Mental disease			17
Epilepsy	5	2	7
Probable psychopath	3	3	6
Slight mental aberration, resulting in failure to think clearly	2	0	2
d. Inferiority complex			34
Timid, retiring nature with decided feeling of inferiority	9	3	12
Compensating for inferiority in other lines	10	1	11
Compensating for inability to do school work by misbehavior in school	5	0	5
e. Abnormal extroversion traits			37
Active, self-assertive, impulsive type	25	7	32
Impulsive, fearless, lacking imagination	2	2	4
Fearlessness and indifference to pain	1	0	1
f. Dullness			112
Inability to appreciate consequences	48	30	78
Deficient intelligence resulting in dislike for school work	25	5	30
Very deficient intelligence making it impossible to manage self or affairs with prudence	1	3	4
g. Abnormal resistance to control			22
High tempered	6	0	6
Arrogant, impulsive nature indifferent to rights and opinions of others	8	0	8
Attempt to escape natural consequences of acts	6	0	6
h. Lack of ethical judgment and insight			28
Lack of ethical judgment and insight	17	9	26
Emotional deficiency	2	0	2
i. Abnormal suggestibility	17	9	26
j. Sadistic tendency	1	0	1
III. Mental conflict			24
a. Based on sex			16
Basis unknown, apparently of sex nature	1	3	4
Based on autoerotic practices	3	1	4
Based on improper sex information	2	1	2

	Boys	Girls	Total
b. Based on parentage			3
Doubt regarding own parentage	1	0	1
Centering around sex and family	2	0	2
c. Based on theft			1
Based on experience with first companion who stole	1	0	1
d. Unanalyzed	3	1	4
IV. Improper sex influences			48
a. Early undesirable information about sex			9
Receiving information from and witnessing improper behavior of other children	3	1	4
Sex phantasy	1	1	2
Hearing other boys talk of fellatio practice	1	0	1
b. Early introduction into autoerotic practices and homosexual practices	23	3	26
c. Early introduction into heterosexual practices	1	4	5
C. Physical			63
I. Defective heredity	14	3	17
II. Defective early developmental condition	13	0	13
III. Abnormal physical condition			33
a. Physical overdevelopment particularly sexual	1	4	5
General overdevelopment about which he is sensitive in the classroom	4	0	4
D. Unclassified			24
Presence of opportunity	10	1	11

IV. Case histories.

Case 1: (boy) chronological age, 27 yrs.; mental age, 13 yrs. 10 mos.

He was high in Boy Scout circles and was detected in the act of engaging in homosexual practices with some of the Boy Scouts in his charge. He was always his mother's favorite and upon the death of his father, a sea captain, she lavished all of her attention and affection on this boy. She made every decision for him. This accustomed him to depend on someone in authority. At the age of seven he was sent to a boarding school where the proprietor initiated him into homosexual practices. The other boyish initiates of this man continued the practice with him. He went from this school to another where practically the same conditions prevailed. Men of prominence in the city, ministers and an organist continued the practice with him. This was also true in the university town where he attended college. At the time he was detected in the act he really felt, due to his experience with these leaders of the community life, that there was little disgrace attached to the practice. He had continued the practice of onanism and homosexuality until he had little or no control of the seminal emissions. This worried him so that he could not concentrate upon his work and further complicated the problem of adjustment.

Case 17: (boy) chronological age, 15 yrs.; mental age, 14 yrs., 2 mos.

This boy was referred by the Juvenile Court after he had engaged in theft of gasoline and oil from a lumber yard, for truancy, and running away. The father, a carpenter, was deeply in debt. In an effort to catch up on his payments, he was working long hours and this left the boy and his younger sister and still younger brother very much to themselves. The boy and his sister

attempted to keep house for the father with very unsatisfactory results. The father was an ignorant, but well-meaning man who could not be made to see the absolute necessity of providing some recreational facilities in the home or attempting to develop family solidarity. This resulted in the children's spending all of their spare time on the streets or at some neighbors with the consequent association, in the case of this boy, with undesirable companions by whom he was initiated into running away, truancy, and stealing. He had a rather remarkable mechanical aptitude which found no satisfactory outlet in the school work offered. He was not interested in academic work and consequently had no incentive to stay in school. In addition to this he had long periods of excessive nose bleed which gave him an excuse to stay away from school and there is little doubt that on occasions he lost so much blood that he was in a weakened condition and unable to do satisfactory school work.

Case 21: (boy) chronological age, 16 yrs.; mental age, 16 yrs.

He was brought to us by his father at the suggestion of the Juvenile Court. He had just stolen a small sum of money from the pocket of his father's coat hanging in his father's office and was confined in the Detention Home. He was 16 yrs. of age. When he was about four or five, his father was divorced by his mother because the father associated with other women. He then went to live with his aunt who reported that he used to steal cookies and other trifles, hiding them about the house if he had no use for them. When he was about six, his aunt had him placed in a feebleminded institute, because he was guilty of some sex misconduct. For five years he lived among mental defectives and after that his father brought him home to live with him in boarding houses and hotels. He has a poor record both at school and at work. He was impudent and unmanageable in school and very unreliable at his work. His moral development was very deficient. This is doubtless due to the fact that he had not learned to govern himself. He always was required to obey authority and never acquired ethical discrimination. He had little affection for his father and resented the latter's efforts of control. He found the excuse for staying out late at night in that his father often did the same thing. His father is a comparatively young man and is not willing to sacrifice his own pleasures for his son's.

Case 34: (girl) chronological age, 14 yrs.; mental age, 12 yrs., 9 mos.

She was referred by the Juvenile Court when it was discovered that she had, in company with a group of other girls and boys broken into a Lakeside cottage and indulged in wild orgies. She had been almost promiscuously immoral. She mentioned 11 boys with whom she had been immoral and stated that she had engaged in such relations 50 times, on some occasions being immoral with four or five in rapid succession. She, with other girls, engaged in a game known as strip poker in which they paid their bets by stripping off all the clothes they had on. The father was a railroad man with a good work record of a number of years. He was away from home much of the time. The mother was known to be the mistress of a man about town who supplemented the father's contribution to the wife by buying clothes and giving her sums of money. He sometimes even bought clothes for the children. The father had been kept in ignorance of this state of affairs, but the daughter knew what her mother was doing. She made the remark that if her mother could act in this way, she did not see why she was not permitted to do so. Two older sisters were following in the mother's footsteps and their almost promiscuous immorality was known to this girl. She was allowed to go with boys at the early age of 13, these boys being several years older than she. She later became acquainted with a number of boys and girls among whom it was considered quite the proper thing to be

immoral. They comprised a small social unit and were not at all impressed by what people outside of their group might think of such behavior. Naturally there was an attempt made to discover new thrills which led to various abnormal practices.

Case 46: (boy) chronological age, 11 yrs., 11 mos.; mental age, 8 yrs, 6 mos.

This boy was referred by the Juvenile Court and the school for running away from home, theft, truancy, and general misbehavior. Both the father and mother had been adopted out of an orphan asylum and were unstable individuals. The father was very loose in his morals and infected his wife with syphilis. The mother herself was known to be immoral. The boy had a positive Wassermann and spinal fluid. He was very nervous, restless, and emotional. The slightest sound caused him to jump and in other ways he exhibited his nervousness. The parents were low grade and showed many evidences of being either moron or imbecile in intelligence. No attempt was made to live up to the commonly accepted social standards in the home. Filth and dirt was plentiful. They were ignorant and indifferent toward the children, for the most part behaving as if they considered them burdens inflicted upon them. On occasions the children were sent to any relatives who would agree to take them. Little supervision was exercised and the children were allowed to go and come as they pleased. This constant changing about from one home to the other did not tend to develop better standards of conduct. The parents were constantly fighting over the question of discipline, as they were over any other question that came up. They often separated for periods of time during which they wrote each other obscene and malicious letters. Mention has already been made of the immorality of the parents. During these periods of separation and even at times while they were living together they indulged in immorality. The children, in roaming the streets, associated with the worst children in the neighborhood. The better children, for the most part, refused to associate with them. The boy was early initiated into and began the practice of onanism. He saw other children engaging in sex activities with the opposite sex and indulged at times with his sister of about the same age as himself.

Case 48: (boy) chronological age, 17 yrs., 10 mos.; mental age, 14 yrs., 6 mos.

This boy was in court charged with having stolen an automobile which he had driven into another city when caught. The father and mother were separated about two years before and when neither would take the responsibility for the boy, he was compelled to go out and obtain employment and support himself. For a time he worked with a construction company, but the work was too hard for the boy who was small for his age. He then obtained employment with a transfer company and slept in the storage barn. He assisted in loading and unloading the trucks and made himself generally useful. He had much time on his hands and few friends. He had become acquainted with a number of older boys who hung around on the corners where they told stories of stealing cars and explained how easy it was and what a good time one could have with a car. This boy was not a good mixer and preferred to be alone for the most part. These stories which he had heard, however, remained in his mind and on one occasion when he was rambling around the streets, what these boys had told him came into his mind and as he had nothing else to do and no money to attend a show, he thought he would take a ride. He found a car with a key in the lock and got in and drove off. He had been wanting to drive an automobile for a long time, but the proprietor of the transfer company was afraid to trust him with one of the trucks. After he had the car, he decided to go to visit some relatives and then go east to search for employment. He was on his way when picked up in a neighboring city and returned to Toledo.

Case 54: (boy) chronological age, 14 yrs., 7 mos.; mental age, 11 yrs., 3 mos.

This boy was referred to me by the Juvenile Court after an epileptic, feeble-minded girl of eleven reported that he had been immoral with her on a number of occasions. It was also discovered that he was constantly truant from school. Examination of the girl and boy brought out the fact that there was no truth in the statement of the girl that the boy had been immoral with her. She masturbated openly and her mind was apparently filled with undesirable sex imagery. The story told about the boy was apparently more a product of her imagination than of real occurrence. This boy lived with his grandparents after the death of his mother when he was three yrs. of age. His father and grandfather were both plasterers and as the boy was large for his age he began several years ago to assist them in their work during the school vacation. In this way he acquired a proficiency in the work and qualified as an expert plasterer. At the time of the examination he could earn from 10 to 15 dollars a day following this trade. Having associated with men and being able to compete on equal terms with men as a plasterer he lost interest in school more especially as he had no real capacity for academic work. Then, too, he was large for his age, and this caused him to be sensitive about being in the room with smaller boys. He felt that he was wasting his time in school as he expected to follow the trade in which he was already expert and the type of schood work offered did not, as far as he could see, increase his ability in his vocation. He showed good practical judgment in the use of his money and saved consistently.

Case 55: (boy) chronological age, 15 yrs., 10 mos.; mental age, 15 yrs., 4 mos.

This boy was referred to the Agency by the employer of the father after he had run away from home with the boy who shot a sergeant of police in Florida. He finally succeeded in breaking away from his companion and returned to Toledo. On the way to Florida he and the other boy had committed a number of thefts and had broken into one or two places after they arrived. The boy with whom he ran away to Florida was a first cousin and was some 2½ yrs. older than this boy. He had always dominated the latter through his fearless and arrogant nature. When he asked his younger cousin to accompany him to Florida and told him he would pay all expenses, the boy who was not very much interested in school anyway, willingly agreed to go. The older boy took a car and picked up the younger boy, and they drove all night. When they arrived in Georgia, the older boy drove up to a filling station at night, and as no one was around he broke the lock and forced the younger boy to hold the hose while he pumped gasoline into the car. After they arrived in Florida the younger boy became homesick and wanted to write to his parents for money to return home, but the older boy produced a revolver and threatened to shoot him if he did this. He compelled the younger one to go with him when he broke into a schoolroom and stole a phonograph and on another occasion when he held up a passing motorist. The younger boy was apparently susceptible to suggestion and easily influenced, particularly by his older cousin.. In describing his behavior he showed a marked lack of foresight which in part accounted for his participation in the thefts with his older cousin.

Case 62: (boy) chronological age, 17 yrs.; mental age, 9 yrs., 4 mos.

This boy was referred by the principal of the Continuation School after the boy had persistently absented himself from school and threatened one of the truant officers who called on him. It was learned at time of examination that he had run away from home on one or two occasions and had attempted to join a gang of criminals. The heredity in this case is decidedly bad. The father presented many of the symptoms of simple dementia præcox. He had "hoboed" his way all over the United States. He and the mother were divorced, because

the father seemed to feel little or no responsibility for his family and felt free to leave and roam the country at any time. At the time of the examination the mother and father were living in the same house, the father paying board. There is also a history of insanity on the mother's side; the maternal uncle having been confined at various times in the state hospital for the insane. When the boy was examined by a psychiatrist upon our recommendation, he was found to present all the symptoms of split personality, blocking, loss of affect, *etc.*, which caused the psychiatrist to diagnose the case as being one of dementia præcox and recommend that the boy be committed to the state hospital for the insane. When we examined the boy in the office he had a history of masturbation starting at about 13. He blamed most of his trouble on this self-abuse. The parents were very ignorant and showed themselves helpless in dealing with the boy. This was true for some time before he was brought to the writer's attention. The history of his mental symptoms went back to about 14 yrs. of age and he had been getting progressively worse since that time.

Case 66: (boy) chronological age, 13 yrs., 9 mos.; mental age, 13 yrs., 6 mos.

This boy was referred to the Agency by the principal of the Industrial School for peculiar behavior in the schoolroom. He could not be induced to recite nor could he be persuaded to do his school work. He was periodically absent from school and never attempted to explain his absence. He persistently refused to look anyone straight in the face and kept his eyes on the floor. He gave the impression of having very weak eyes but examination disclosed nothing wrong with them. When he was finally persuaded to talk he stated that he was terribly ashamed of himself and finally admitted that it was because of his inability to overcome the habit of masturbation. Pictures in magazines served to initiate his masturbation tendency. He had felt that everyone on the street knew about his masturbation and he had an intense feeling of inferiority and shame centering around this. He was naturally of a seclusive, brooding, introvertive type and would associate with none of the other boys in the neighborhood nor even with relatives when they came to visit him. Their appearance was a signal for him to leave the house and retire among the bushes in the backyard where he stayed until the visitor left. He did not participate in group activities and took little or no physical exercise. It was very difficult to get him to talk above a whisper. He showed many symptoms of beginning dementia præcox, such as retardation and loss of affect. He began indulging in autoerotic practices when he was about eight yrs. old after he had seen other boys engaging in these practices while in swimming. From that time on he apparently began withdrawing to himself and with the onset of adolescence this tendency became more and more marked. He showed an unusual timidity in the presence of other people and dressed under the covers to prevent anyone from seeing him.

V. Complexity of causations. One of the outstanding impressions which a study of the causations of delinquency conveys is the tremendous complexity of these causes to be found in the individual delinquent. It seldom happens that to one factor can be ascribed the larger influence in causing delinquency. Almost invariably there is to be found not one but many causes operating in a given case. The tendency on the part of popular writers and speakers to ascribe all delinquency to broken homes, prohibition,

automobiles, *etc.*, finds no confirmation in a careful study of individual delinquency. Delinquency is an individual matter and generalities aid very little in understanding and adjusting the individual delinquent. There is little doubt but that certain favorable general conditions such as proper recreational facilities, adequate provision for meeting the needs of the individuals in the schools and suppression of vicious environmental surroundings, adequate vocational training and guidance, adequate parental supervision and control operate to prevent the development of delinquency in children. This does not mean, however, that generalities as to home conditions, recreational facilities, *etc.*, will serve to explain the delinquency in a particular case.

It would take entirely too much space to give a detailed analysis of the list of causations showing the numerous combinations of these causes. We propose here to mention in a general way some of the possibilities of combinations.

1. Lack of supervision and discipline. This may be the result of a great variety of conditions. The parents may be low grade in intelligence and unable to appreciate the need for such discipline. The nature of their work may prevent them from exercising proper supervision and discipline. Early experiences, such as harshness on the part of their parents may have caused them to resolve to indulge their own children. Sometimes illness on the part of one or both parents results in lack of supervision and discipline.. Many times the parents are so much interested in other things that the child receives very little attention. Absence on the part of one or both parents, brought about by a number of different causes, may prevent them from exercising adequate supervision. Occasionally the parents are dead and no one is present who is enough interested in the child to supervise him. In his discussion of causations the writer has not gone back beyond the lack of supervision and discipline unless the antecedent cause of this condition was also a factor in the child's delinquency. From whatever cause, lack of supervision and discipline on the part of parents or guardians offers many opportunities for other undesirable influences to operate upon the child. He has so many opportunities to come in contact with bad com-

panions of many kinds. He also acquires attitudes and behavior patterns which may reach the development of mental abnormality. He is likely to acquire undesirable information, particularly of a sexual nature. Along with this lack of supervision and discipline goes very often friction between the boy and members of his family. Often the lack of supervision and discipline is especially prevalent in those districts where juvenile lawlessness abounds and where little provision is made for satisfactory recreational and other interests.

2. *Friction in the family.* This again may be due to a number of causes such as illness on the part of the mother making her unduly irritable, example set by father, partiality on the part of parents, or other conditions. In the list of causations, an attempt has been made to point out the cause of the friction when this could be definitely determined. Friction in the family may be associated with a great variety of other conditions. It tends to cause the child to get away from home and the atmosphere of friction. When away from home opportunities for association with bad companions are usually present. This situation very often leads to a lack of interest in school work, particularly where this is one of the elements in causing the friction. It often results in mental abnormalities and peculiarities, such as some form of instability, abnormal introversion, or an inferiority complex. Occasionally it tends to develop abnormal extrovertive traits or an abnormal resistance to control. Of course association with bad companions creates opportunities for improper sex information.

3. *Other undesirable environmental conditions.* One is continually impressed with the desirability for normal parental supervision and control in a normal home. Perhaps the growing tendency to care for deficient children in boarding homes rather than in institutions is based upon a knowledge of the failure of institutions properly to develop attitudes and moral standards which safeguard the individual in his social adjustments on the outside. Many undesirable influences come from throwing young children into too intimate contact with each other and failure to choose with proper care the individual who has control of them. Case 1 illustrates this in perhaps its worst form. Case 21 illustrates

another, if rather unusual result of institutional treatment. Changing home conditions make for the development of personality traits which are very undesirable. Particularly to be mentioned in this connection is the instability and irresponsibility which arises from these circumstances. Poverty has received its due measure of attention from many writers. It has been pointed out that poverty is due to a number of different causes and its results manifest themselves in many ways. Poverty is usually accompanied by low moral standards and ignorance in the home. It is frequently associated, too, with a bad neighborhood and bad companions. It is usually accompanied by defective recreational or other interests and may help to cause certain mental abnormalities and peculiarities, such as instability and the lack of ethical insight and judgment. Sometimes it is the cause of defective early developmental conditions and abnormal physical conditions in general.

4. Lack of family solidarity. This may be caused by preoccupation of the father with business and of the mother with social activities, or it may be due to ignorance and indifference on the part of the parents, as well as a number of other causes, but regardless of the causes it increases opportunities and temptations for antisocial conduct on the part of the child. It is usually accompanied by improper supervision and control on the part of the parents. It may also be accompanied by low moral standards and defective or unsatisfied interests. It opens up the way for the influence of bad companions and the development of mental abnormalities and peculiarities. Death of one of the parents and the attempt on the part of the other to supervise the child often results in failure to exercise the proper control. It is seldom possible for the parent so situated to protect his child from influences of bad companions or to develop proper recreational interests. Confidential relationships between the child and his parents furnish the best safeguard against most of these antisocial influences mentioned above. Very few cases of delinquency occur where confidential relationships exist between parent and child.

5. Low moral standards. These may be due to ignorance, faulty training, defective intelligence or a number of other con-

ditions, but their influence upon the child is decidedly vicious. The child reacts by adopting these standards for his own or develops a mental abnormality based upon them. Particularly to be mentioned in this respect are abnormal introversion and inferiority complex. The child may also develop an abnormal resistance to control or a mental conflict centering around these anti-social acts on the part of the parents. Case 34 illustrates this condition in the case of a young girl. Case 46 illustrates a combination of this factor of causation with many others.

6. *Too much supervision and discipline.* Many parents fail to realize that the child must have an opportunity to develop through trial and error and attempt to regulate in the closest detail every activity of his daily life. This fails to develop initiative and independence in the child and when later he sets forth on his way to social adjustment, he is likely to develop, or at least manifest, a number of undesirable traits. He seems to be particularly susceptible to suggestion, and bad companions are a potent source of the suggestions which are likely to come to him. Perhaps through this constant supervision, he has had no opportunity to develop desirable interests, either recreational or vocational, and, consequently, is at the mercy of chance suggestions. He is usually irresponsible and lacking in foresight. He may develop an inferiority complex because of his inability to do what other boys are doing. This may attain the proportions of a mental conflict.

7. *Neighborhood.* Many cases of delinquency can be traced back to the influence of a bad neighborhood where juvenile delinquency was prevalent. This is usually to be explained on the basis of bad companions found in these neighborhoods, but occasionally the physical features of the neighborhood offer a powerful incentive to delinquency. These cases of purely environmental, apart from a social influence operating to cause delinquency, are exceptional. Delinquency can usually be traced back to a direct or indirect influence of the individuals who live in the bad neighborhood.

8. *Bad companions.*

a. Companions not delinquent but influencing to delinquency through suggestion or fear of punishment. A number of delin-

quents become so thoroughly under the influence of companions who are not necessarily delinquent but who give antisocial suggestions to the child that delinquency results. Sometimes the delinquent is merely the tool of another boy who never participates in the delinquency himself but reaps the benefits of the delinquent act. Many cases are influenced to delinquent behavior by stories of thefts and sex experiences which may have originated in the fertile imagination of the informer, or the child may have misconstrued what he heard and may have brooded over it until it became an incentive to misbehavior. The results of this suggestion may take any form of delinquency and may be accompanied by defective or unsatisfied interests or mental peculiarities of many forms. This suggestion of bad companions may be, and usually is, one of the causes of delinquency in an individual case. In this connection attention is called to cases 48 and 55. The companion may not have intended to give antisocial suggestions or to exert any influence in this direction, but the result was just the same. Sometimes the young delinquent is so controlled by fear of an older or strong companion who is able to dominate him that he commits any delinquency suggested by this companion.

b. Lawless companions. Very few children can associate with lawless companions without adopting their attitudes and behavior reactions. They influence some directly and their influence may or may not be accompanied by the development of mental abnormalities and peculiarities and other undesirable conditions.

c. Companions engaging in sex perversions. A boy who is thrown in contact with companions engaging in sex perversions is at first horrified and then gradually develops matter of fact attitudes towards the practice and later begins to indulge in it. Sometimes it results in a mental conflict along with the bad practice and it may distract his interest from desirable recreational and vocational activities. It may develop along with faulty sex interests into mental abnormalities and peculiarities. Sometimes these may reach the proportions of a mental disease. (See cases 62 and 66.)

d. Immoral companions. Along with the breakdown of the

normal moral standards which the individual may have developed, immoral companions present the danger of venereal disease. Abnormal interest in sex matters and mental abnormalities and peculiarities often result from association with immoral companions. A case falling under any one of these types of bad companions may also be included under other forms of bad companions, as well as defective home conditions, bad neighborhood conditions, or any other of the types of causation. The presence of bad companions, in other words, does not preclude the possibility of any other cause operating to cause delinquency.

9. Defective or unsatisfied interests.

a. Defective recreational interests. These may arise from too much or too little supervision in the home, lack of recreational facilities or a large number of other causes and may take the form of an abnormal interest in undesirable or antisocial activities. This condition may be accompanied by defective home conditions, bad companions, mental abnormalities, and peculiarities, mental conflict, improper sex influences, defective heredity, or abnormal physical conditions. In other words, the range of cases falling under defective or unsatisfied interests will be found to include most of the forms of causations in the etiology of their delinquency.

b. Educational and vocational. It is obvious that these situations may arise from a number of different sources and may be accompanied by a great variety of other conditions which tend to bring about antisocial conduct on the part of the boy or girl. Defective home conditions may be an antecedent condition to defective or unsatisfied educational and vocational interests. Perhaps accompanying this defect may be found mental abnormalities and peculiarities or an abnormal physical condition. Case 17 illustrates abnormal physical conditions accompanying defective or unsatisfied interests. Frequently it is not a case of a defect in the interest of the individual, but lack of adequate facilities for providing for his interests. Case 54 illustrates this very clearly. It is obvious that defective or unsatisfied educational and vocational interests may be accompanied by defective

home conditions, mental abnormalities and peculiarities, and sometimes even by mental conflicts.

10. Mental abnormalities and peculiarities. Reference to the case histories discloses the fact that an individual may be suffering from more than one of these abnormalities, and in addition, defective home conditions of many different kinds may be present. Bad companions may bring their influence to bear; defective or unsatisfied interests, and abnormal physical conditions of various kinds may contribute. Presence of a mental abnormality or peculiarity does not eliminate the possibility of other causes of delinquency operating in a given case. Mental conflict, based upon or accompanied by improper sex influence, may also be present. The abnormality itself may have its cause in defective heredity or defective early developmental conditions. It is often extremely difficult to decide just to what extent the mental factors of causations compare in importance with the physical or the social and environmental causes of delinquency. All of these are so inextricably mixed up in their influence upon the young delinquent that it becomes almost impossible to determine the degree of importance of each of them. Many cases of mental abnormality and peculiarity can be traced back to defective home conditions, bad companions, or physical abnormalities and where the influence of one ceases and the other begins is pretty largely a matter of opinion.

11. Mental conflict. This is usually accompanied by, or is the result of, bad companions, but the opportunity for these companions to influence the individual may be due in turn to lack of supervision and control on the part of the parents. The effect of the influence of bad companions would have been neutralized by confidential relationships existing between the child and the parents. Of course, mental conflict may be accompanied by a number of other conditions tending to cause delinquency but usually these cases show a lower degree of complexity of causation than those where other causes are the major factors in the delinquency.

12. Improper sex influences. This can practically always be

ascribed to undesirable companions. There are a few cases where abnormal physical conditions and perhaps mental abnormalities and peculiarities accompanied improper sex influences as causes of delinquency. Here again lack of proper sex information, which should have been given by the parent, may be indirectly a cause of the operation of these improper sex influences in causing delinquency.

13. Abnormal physical conditions. Abnormal physical conditions may accompany any one of the causes described above. The possibilities of combination in this field are almost unlimited. Mention has already been made of the interrelationship between physical and mental causations and the difficulty of determining the extent to which each is a factor in causing the delinquency of a given case.

VI. Conclusions. With such a mass of material as one finds, it is difficult to draw conclusions without doing violence to the complexity of causations and their interrelations. An attempt will be made to present certain conclusions which seem important and which may serve as a guide in studying and understanding the young delinquent. These conclusions are based entirely on the data disclosed by the study and it is hoped that some additional light will be thrown on the problem.

1. In studying delinquents, it is imperative to utilize all the sources of information available. Among these may be mentioned the social agencies which have had contact with the family from a relief or health standpoint, the schools, the parents, relatives, and friends. While at times one or more of these sources of information fail to assist materially in understanding the delinquent, the likelihood of acquiring valuable information is too great to permit the conscientious and thorough investigator to ignore any of them. Frequently a suggestion of the key to the problem will be found in the information to be obtained from the above sources. The effort required to obtain this information is decidedly worth while. It is not sufficient to depend upon the delinquent acts for all the leads to be followed in the inquiry. Deep-rooted and hidden but important facts will be missed by this method, such as the child's general defective heredity, friction in the family,

or a number of other conditions. There is no guarantee that such conditions are not presenting and exerting a powerful influence in the direction of antisocial behavior. To discover these it is necessary to delve into many fields of inquiry.

2. Every delinquent act is the direct result of some mental process and can be understood only if the nature of these antecedent mental elements is understood. This indicates the necessity for a careful investigation of the mental constitution of the young delinquent. Information obtained from the scurces mentioned above is important chiefly for the reason that it discloses the manner of influences which have been playing upon the child. Whether these are effective can be determined only by an analysis of the mental processes of the young delinquent. Social, environmental, and physical conditions depend for their importance upon their mental result upon the child. Too often one sees other children living under the same conditions and in the same general atmosphere as the delinquent sibling, with no apparent tendency toward misconduct. We must therefore not place too great an emphasis upon undesirable environmental conditions as the cause of delinquency. Quarreling and other irritative conditions apparently have no effect upon one child while another in the same family is moved thereby to engage in delinquency.

3. The most important single factor to be considered in the study of the delinquent is to discover the conditions surrounding the acquirement of his first information about delinquent behavior. It is here that one finds the important elements of causation. Later events may supplement but can never supplant the first acquirement of antisocial information in importance. This information is usually obtained from other individuals and the first individual to impart such information wields a tremendous influence over the learner's future. Time after time one is impressed by the remarkable hold the former has over the latter who will violate his own ethical principles at the command of the other. Parents have at hand the opportunity to acquire this influence by imparting information in a wholesome way.

4. Perhaps the most important conclusion to be drawn from the data given above is relative to the multiplicity of the causes

of delinquency. The original list included more than 300 causes appearing in the individuals studied. Combinations were made where possible which brought the total to 217.

5. The next important conclusion emerging from these data is that delinquency causations are unbelievably complex. It frequently happens that no one factor is responsible for the main influence in causing delinquency. Almost invariably not one but many causes are operating in a given case.

6. There is little or no connection between the form delinquency may take and the type of causation. Defective home conditions may result in incorrigibility, running away, stealing, sex offenses, truancy, or almost any other form of delinquency. The same is true of faulty interests and other types of causations. The delinquency is merely a symptom of maladjustment and seldom indicates the kind of maladjustment.

7. Many forms of delinquency are obviously the result of too much concentration of population in cities and the complications arising from such concentration.

8. Defective home conditions appear most frequently as an inciting cause of delinquency, with mental abnormalities and peculiarities a close second. Bad companions appear third in order of frequency. Faulty interests, improper sex influences, abnormal physical conditions, mental conflict, defective heredity and defective early developmental conditions follow in the order named.

9. The following table gives the order of frequency and number of cases found under each of the subheadings:

Order of Importance of Causations

Lack of supervision and discipline	147
Lawless companions	147
Dullness	112
Other undesirable environmental influences	69
Friction in family	62
Low moral standards in family	62
Companions not necessarily delinquent but influencing to delinquency	46
Instability	40
Abnormal extroversion	37
Immoral companions	35
Educational and vocational defects	34

Inferiority complex	34
Abnormal physical condition	33
Recreational defects	30
Lack of ethical judgment and insight	28
Abnormal suggestibility	26
Neighborhood influences	24
Unclassified	24
Abnormal resistance to control	22
Defective sex interests	19
Defective heredity	17
Mental disease	17
Mental conflict based on sex	16
Early introduction into autoerotic practices	16
Abnormal introversion	13
Defective early developmental conditions	13
Early introduction into homosexual acts	10
Early undesirable information about sex	9
Companions engaging in sex perversions	8
Too much supervision and discipline	7
Early introduction to heterosexuality	5
Unanalyzed mental conflict	4
Mental conflict based on parentage	3
Mental conflict based on theft	1
Other abnormalities and peculiarities	1

10. Lack of supervision and discipline is primarily due to general lack of control from a variety of causes, absence of one or both parents, pampering by mother, and indifference on part of parents, in the order named.

11. Friction in the family is chiefly due to friction between parents on question of discipline, father unreasonable in his discipline, and presence of step-parents in the above order.

12. Other undesirable environmental influences seem to be due to poverty, no home life, changing home conditions, lack of family solidarity, mother dead, father and children keeping house, respectively.

13. Low moral standards are chiefly due to ignorance on part of parents with a variety of other causes tending to create the same conditions.

14. Too much supervision and discipline operates to cause delinquency when the parents make all decisions for the child and thus hamper his moral development.

15. Bad neighborhood conditions are chiefly due to the presence of adult and juvenile lawlessness although the physical elements of the environment may also cause delinquency.

16. Bad companions are important in causing delinquency. Lawless companions are the most frequent cause with suggestive, immoral, and perverted following in the order given.

17. Faulty interests are frequent causes of delinquency. Those having to do with education and vocation rank first with recreational and sex interests ranking second and third respectively.

18. Mental abnormalities and peculiarities show the following relative importance in causing delinquency: (a) dullness, (b) instability, (c) abnormal extroversion, (d) inferiority complex, (e) lack of ethical judgment and insight, (f) abnormal suggestibility, (g) abnormal resistance to control, (h) mental disease, and (i) abnormal introversion.

19. Mental conflict in delinquents is based most often on sex but parentage and theft may also serve as a basis.

20. Improper sex influences come most often through early introduction into auto-erotic practices with early introduction into homosexual practices, early undesirable sex information, early introduction into heterosexual practices appearing in the order named.

21. Physical conditions influencing to delinquency have the following order of frequency: (a) abnormal physical conditions, (b) defective heredity, (c) defective developmental conditions.

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